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A STUDY ON THE STRUCTURE OF THE EGG OF THE WALKING-STICK, DIAPHEROMERA FEMORATA SAY; AND THE BIOLOGICAL SIGNIFCANCE OF THE RESEMBLANCE OF PHASMID EGGS TO SEEDS.*

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(With Plate IX.)

A detailed description of the eggs of the walking-stick is essential because in the systematic work on the Phasmidae, the eggs are said to be a very valuable auxiliary means of identification, since their form, "für die Genera charakteristisch ist." (Brunner von Wattenwyl†). Kaup (8) even remarks, "Vielleicht wird man später die Arten durch die Eier schneller unterscheiden lernen als durch die Thiere selbst!"

Measurements of Eggs: Heymons (6) found with Bacillus rossi that the size of the eggs is not constant. "Es sind mir Eier zugekommen, wahrscheinlich die letzten, welche das Weibchen abgesetzt hat, die höchstens die Hälfte der üblichen Grösse besassen, trotzdem waren sie aber normal gebaut und es sind aus ihnen ebenfalls Larven ausgeschlüpft." In Diapheromera femorata a considerable variability in the dimensions of the eggs is also present but the smaller eggs were not necessarily the last ones which the female lays,—they may appear among the first or at any time during the egg-laying.

The size of the eggs varies between the following dimensions:

Length	20–29 mm.
Depth, from dorsal to ventral surface	11–18 mm.
Width or thickness from side to side	9–14 mm.

* Submitted as a part fulfillment of the thesis requirements for the degree of Ph. D. at the University of Wisconsin.

† Paper not accessible. Quoted from v. Brunn's (2) paper.

The majority of eggs varied between the following dimensions:

Length	25–29 mm.
Depth	15–17 mm.
Width	12–13 mm.

Shape and Color of Egg: The eggs resemble very small beans with some variation in shape; some are ellipsoid, others ovoid and still others nearly spherical in form. Their color is usually a glossy black, except on the slightly more convex side which is white; instead of the black, however, there may be light shades of gray or light chocolate-brown. Out of a thousand eggs, twelve showed the light shades of gray and only three, the light chocolate-brown color.

When the operculum is removed the egg, in this region, is obliquely truncate and surrounded by an elliptical or oval rim. On the inner margin of this rim rested the operculum. The rim is provided with a circle of yellow, chitinous, bristle-like projections. In most eggs the white color of the slightly more convex side is continued around the base of the rim as a white line.

Operculum: The operculum (Fig. 1, *op*) fits perfectly within the rim of the egg capsule (Fig. 1, *ri*) and is usually set free when the egg is broken. If the operculum is cleared, mounted and examined under the microscope a ragged membrane is discernible at its margin (Fig. 3, *vi*). This is the torn, so-called "shell membrane" to which the operculum was attached.

Sharp (16) who has described a number of Phasmid eggs, has probably overlooked the fact, that the operculum is attached to the so-called "shell membrane." He writes, the operculum "is present in all known eggs of the Phasmidae; it is a lid that fits very accurately to the truncate anterior extremity of the egg; its margin is surrounded by a margin of the capsule, and it is owing to the perfect fit between the two that the operculum retains its position." Müller (13), however, in the case of *Phasma ferula* claims that, "Am Rande des Ausschnitts springt die innere Schalenhaut etwas vor, ein Rudiment der Verbindung der Schale mit dem Deckelchen. Die innere Haut des Deckelchens und die innere Haut der Schale sind also an dem unverletzten Ei ein Continuum." Leuckart (10) who has worked on the structure of the eggs of two species of Phasmids belonging to different genera also finds that, "Durch Hülfe dieser Schalenhaut wird der Deckel, der sonst vollkommen isolirt ist, in seiner Lage erhalten und befestigt."

A number of zoologists who have worked on the structure of the eggs of the Phasmidae claim that a "shell membrane" exists within the inner surface of the chorion. Müller (13) writes, "Die innere Fläche der Schale wird von einer sehr dünnen häutigen Lamella, *der Schalenhaut*, überkleidet, die sich nur in kurzen Stücken von der Schale selbst wegnehmen lässt." Leuckart (10) agrees with Müller that a "shell membrane" lines the inner surface of the chorion. "Dazu kommt als Bekleidung der innern Chorion-fläche noch eine eigne dünne 'Schalenhaut,' die schon von J. Müller aufgefunden ist, also wahrscheinlich unter den Phasmoden eine ziemlich allgemeine Verbreitung hat, obgleich sie den übrigen Insekteneiern abgeht." In the eggs of Diapheromera femorata the so-called "shell membrane" is the innermost layer of the chorion, which peels off in small fragments in the eggs that are in the early stages of development, but in the later stages, as Leuckart (10) has observed, "Bei *Cyphocrania* lässt sich diese Haut ohne grosse Schwierigkeiten in continuo abheben —bis auf die Narbe, an der dieselbe fest mit dem Chorion verwachsen ist und ein weisses Aussehen hat." To Leuckart's observation may be added, in the case of the eggs of Diapheromera femorata, that a firm attachment also exists at the rim between the so-called "shell membrane" and the next outer layer of the chorion.

A microscopical examination of the operculum from the outer surface shows a resemblance to the framework of a dome, which is shut off at the base by a slightly concave floor of chitin. The framework consists of brownish, irregularly-flattened, chitinous rods. All of these rods arise from an elliptical or oval brownish rim of chitin (Fig. 3, *br*) which is in continuation with the similarly colored upper surface of the floor of the dome (Fig. 4, *e*). Some of the rods anastomose, enclosing a large, more or less, central space at the top of the dome (Fig. 3, *c*) and a varying number of irregular areas (Fig. 3, *d*) which are not constant in number in the different opercula. Those rods which do not extend to the top of the dome project free into the irregular spaces (Fig. 3, *p*).

Various authors have called attention, in different Phasmidae, to the resemblance in the histological structure of the egg capsule to the structure of certain plant tissue. Murray (14) finds, "a most striking resemblance to a piece of honey comb" in the structure of the egg capsule of *Phyllium Scythe*. Accord-

ing to Joly (7) who has worked on the structure of the egg of *Phyllium crurifolium* "ce tissu présente la plus grande analogie avec celui du liège, c'est-à-dire qu'il est formé de cellules irrégulières (carrées, pentagonales, sexagonales) très petites et très serrées. La couche extérieure qui recouvre cette coque, est beaucoup plus épaisse et, comme nous l'avons dit, elle ressemble à l'ecorce rugueuse du Chêne-liège, dont elle a la légèreté. Nouvelle et curieuse analogie de notre insecte avec le règne végétal: analogie qui devient plus complète encore, quand on songe que l'oeuf du *Phyllium* est muni d'un opercule qui s'ouvre lors de l'éclosion, à la manière d'une pyxide." Brongniart* who has examined the eggs of Phyllium pulchrifolium also compares the external envelope to that of cork. According to Henneguy (5) who has also worked on the histological structure of the egg-capsule of Phyllium crurifolium, "L'ensemble de la couche externe présente une grande analogie de structure avec la partie libérienne d'une écorce de dicotylédone traversée par les rayons médullaires."

A cross section through the operculum of the egg of Diapheromera femorata shows that the space between the floor and top of the dome is partially filled with chitinous deposits, which, according to a vegetable histologist, resembles somewhat the thin walled parenchyma of plant tissue, except that no middle lamella was discernible (Fig. 4, *a*). Müller (13) describes the chitinous deposition as "ein zelliges Gewebe aus deutlich sechseckigen oben offenen Zellen bilden. Dies scheint einer besonderen Beachtung werth, da die Ercheinung eines regelmässigen zelligen Gewebes in der Organisationsstufe der Insecten gewiss die seltenste ist." It would be rash to speculate as to the formation of this chitinous deposition since the manner in which the operculum is formed is obscure. Sharp (16) suggests two methods: "first, autotomy of the pole of the egg; second, adhesion of the mass of matter from the adjacent nutrient chamber, to form as it were a very imperfect second egg."

"*Hilar area, cicatricula or Narbe*" of *Egg:* On the outer surface of the exochorion, of the slightly more convex side of the egg is an elliptical region resembling somewhat the hilum of a seed. Sharp (16) calls this region the "hilar area," Müller (13) the "cicatricula" or "Narbe," Leuckart (10) and Heymons (6) also use the term "Narbe." The margin of this "hilar area"

* Paper not accessible. Quoted from Henneguy's (5) paper.

is slightly elevated and buff-colored (Figs. 1 and 8, *m*). At the posterior end, this margin narrows enclosing a semicircle (Figs. 1 and 8, *s*) within which lies the micropylar orifice (Figs. 1 and 8, *o*). The margin of this semi-circular area is in continuation with a ridge which extends towards the posterior pole of the egg. The buff-colored ridge joins a triangular extension of the black region of the egg (Fig. 1, *r*) and gradually disappears as it passes posteriorly into the surrounding black surface. Within the slightly elevated buff-colored margin is a white convex region which terminates at the posterior end in the microypylar orifice, where the white color gives way to black (Figs. 1 and 8, *o*).

Mycropylar Apparatus: Müller (13) did not understand how eggs of insects with a hard chorion were fertilized and he takes an extreme view as to the way this phenomenon takes place in the eggs of the Phasmidae. "Bei den *Phasmen* hat die Samenkapsel ausser ihrer einen Oeffnung nach aussen keinen besondern Ausführungsgang. Aber der Eingang der zweihörnigen Samenkapsel liegt gerade über dem länglichen Ausgang des Eierganges. Der Samen tritt also aus der Eingangsöffnung der Kapsel unmittelbar in der Mündung des Eierganges ein, um sofort zu den Eierleitern und Trompeten zu gelangen."

"Wir haben aber bewiesen, das eine Befruchtung der Phasmeneier nicht anders, als vor ihrer Ausbildung und namentlich vor der Ausbildung der Schale, möglich sey."

The micropylar apparatus is very remarkable and differs from any of those which Leuckart (10) has described for so many insect eggs. As already mentioned the micropylar orifice is found at the posterior end of the convex area, just within the space enclosed by the semicircular chitinous thickening of the margin. This opening leads into a small canal, the micropylar canal, which passes a short distance towards the anterior pole of the egg. The micropylar canal is elliptical in cross section and surrounded by extremely thick chitin (Fig. 5, *g*). When the inner surface of the "hilar area" in the region of the micropylar apparatus is examined under a microscope, an invagination of the inner surface of the chorion is readily seen; at the bottom of this inpushing is the opening of the micropylar canal (Figs. 6 and 8, *i*). If the vitelline membrane in this region is now examined under a binocular, one finds that a small, obliquely-inclined, membranous tube has been torn away from the opening of the canal (Fig. 2, *t*). A glance at Fig. 7, *v*, shows the opening

of this membranous tube, the vitelline membrane micropyle, into the vitelline membrane. The sperm thus enters the micropylar orifice, passes through the micropylar canal, then through the membranous tube and out of the vitelline membrane mycropyle to reach the egg.

Müller's (13) supposition that the sperm passes from the seminal receptacle, through the common oviduct, then into the oviducts to the ovarian tubule and fertilizes the egg before the chorion is formed is entirely erroneous. Leuckart (10) from observations on Gomphocerus found that the micropyles, "nicht von Anfang an dem Chorion zukommen, sondern erst nach der Ablagerung desselben durch Resorption ihren Ursprung nehmen * * * * . Eine Bestätigung dieser Beobachtung finde ich darin, dass ich nicht selten (wie u. a. bie Borborus, Tetanocera und verwandten Fliegen) Eierstockseier antraf, deren Micropylapparat noch ohen Oeffnung war, sonst aber bereits vollkommen entwickelt schien."

"Vor der Ablagerung des Chorions habe ich an der Dotterhaut niemals eine Micropyle wahrgenommen * * * * . Wohl aber habe ich Fälle beobachtet, in denen bei Anwesenheit der Chorionmicropyle die Dotterhaut noch ohne Loch zu sein schien." In all probability the eggs of the walking-stick are fertilized as they pass below the opening of the seminal receptacle.

The Biological Significance of the Resemblance of the Phasmid Eggs to Seeds: A number of naturalists have called attention to the striking resemblance of the Phasmid egg to a seed. In some cases, the egg resembles the seed of the natural food plant of the insect.

In seventeen species of Phasmids obtained from Lifu and New Britan, Sharp (16) has described the eggs of a number of these. In regard to the resemblance of the eggs to seeds he writes: "The climax of the peculiarities is found in the extremely perfect structure of their eggs and the resemblance of these eggs to seeds. The egg of the Phasmid has not only a general resemblance in size, shape, colour, and external texture to a seed, but the anatomical characters of certain seeds are reproduced on the external surface, there being a hilar area, a hilar scar, and a capitulum corresponding to the micropylar caruncle of such seeds as those of the Castor-oil plant (Ricinus communis). The hilar area on the inner surface of the capsule is, in shape, like the embryo of a plant. Moreover, naturalists who have examined these eggs

declare that the minute structure of this curious egg-capsule cannot be distinguished histologically from plant-structure."

Among the leaf-insects the resemblance of the eggs to seeds is especially marked. Nab* as early as 1854 has compared the egg of one of these leaf-insects to the seed of the "Belle-de-Nuit (*Mirabilis Jalapa*)." Henneguy (5) in the case of the egg of Phyllium crurifolium claims that, "Sa forme est celle d'un akène d'Ombellifère, et représente, par example, la moitié d'un jeune diakène de *Conium maculatum*. L'oeuf diffère de l'akène d'Ombellifère en ce que son opercule régulièrement conique, est situé au centre de sa face supérieure, tandis que le style conoïde de l'akène est aplati sur la face commissurale." Morton (12) in this same species writes that the "egg has been confused with a seed of Mirabilis and Coniom!"

According to Stockhard (18) the walking-stick, Aplopus mayeri, is found only on its food plant, *Suriana maritima*. "While one may find a close resemblance in size and color between the eggs of *Aplopus* and the seed of *Suriana*, both of which fall from the branches to the ground, where they are obscured among the débris" yet the eggs differ from the seeds considerably in shape.

The eggs of Diapheromera femorata were shown to a number of botanists, and with one exception, all mistook them for seeds. The botanist who did not fall into this error broke the egg before giving his opinion. When asked as to what seed the egg resembled all failed to recall any particular one. A leguminous seed, such as a small bean, was suggested, but none could be found in the natural habitat of Diapheromera, that resembled its egg in size and color.

If these botanists are unable to distinguish the egg of a walking-stick from a seed, can a grain-eating bird distinguish between the two? If a bird were to feed on the seeds of the Suriana maritima which resemble the eggs of Aplopus mayeri in size and color, could the bird discriminate between the two, on account of a difference in shape?

Goldi (4) in the case of the eggs of two Brazilian walking-sticks raises the question as to how far this imitation is useful in the protection of these eggs. Grain-eating birds may eat the egg but general insectivorous birds would probably mistake it for a seed and leave it untouched. The protective dress of the

* Quoted from Henneguy's (5) paper.

egg may be only a relative protection in which new dangers are involved. He next raises the argument that these eggs on account of the resemblance to some Brazilian seeds, deceive, so he believes, the egg-parasites.

This would imply that through the sense of sight the egg-parasite would overlook the eggs on account of their resemblance to some Brazilian seeds. It is open to serious question whether the egg-parasites are guided to the eggs of their host through the sense of sight alone, if at all. One illustration will suffice. We (15) have found that Trichogramma pretiosa parasitizes the eggs of Cimbex americana, and yet the egg-parasite cannot see the eggs of its hosts as Cimbex deposits its eggs in a receptacle within a willow leaf. In all probability, the sense of smell plays an important role in guiding the egg-parasites to the eggs of their hosts.

A careful survey of the literature shows that the eggs of Phasmids are subjected to the attack of a number of enemies. According to King (9) the eggs of Anisomorpha buprestoides "are victimized in a similar manner by a minute species of Ichneumon fly, one of which has fortunately been obtained; it is probably one of the Chalcididae: all the transformations take place within the egg, and when fully developed the perfect Ichneumon fly emerges therefrom."

Bates (1) "observed that the author of the note was probably in error in attributing the name of Anisomorpha buprestoides to the species in question, which seemed to be a true Phasma."

Smith (17) "remarked upon the peculiarity of all the transformations of the Chalcidite parasite taking place within the egg of the Phasma; such a mode of development was novel, if true, but he suspected some error of observation."

M'Lachlan (11) "suggested that the cocoon of the Chalcis had been mistaken for the egg of the Phasma."

von Brunn (2) records the observation of Wolff von Wülfing, that the young larvae as well as the eggs have many enemies, "hauptsächlich Springspinnen und Hauseidechsen."

Girault (3) in his paper on the "Hosts of the Insect Egg-Parasites in North and South America" does not record an egg-parasite from any Phasmid.

I think that the resemblance of the eggs to seeds has no biological significance as a means of protection against the egg-parasites, if the eggs of the Phasmidae are parasitized. Sharp (16)

in all the species which he has examined believes that these resemblances in the eggs have no bionomic importance for the species and I am strongly inclined to accept his view in the case of the egg of Diapheromera femorata.

I am indebted to my teacher and friend, Prof. Wm. S. Marshall, for many valuable suggestions in this work and the more than ordinary courtesies extended to me in the use of his excellent entomological library.

Zoological Laboratory, University of Wisconsin, Madison, February 1, 1910.

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Explanation of Plate IX.

All figures were drawn with a camera lucida.

Fig. 1. "Hilar area" on the slightly more convex side of the egg: *op*, operculum; *ri*, rim in which the operculum fits perfectly; *m*, margin of the "hilar area"; *s*, semicircular margin; *r*, buff-colored ridge which passes over into the triangular extension of the black region of the egg; *o*, micropylar orifice.

Fig. 2. Vitelline membrane of egg, after the chorion of the "hilar area" has been removed: *t*, membranous tube, which connects with the opening of the micropylar canal on the inner surface of the chorion.

Fig. 3. Operculum from the outer surface: *vi*, torn so-called "shell membrane" to which the operculum was attached; *br*, brownish rim of chitin from which the irregularly-flattened chitinous rods arise; *c*, large, more or less, central space at the top of the operculum enclosed by the anastomosing rods; *d*, irregular areas which are not constant in number in the different opercula; *p*, rods which project free into these irregular spaces.

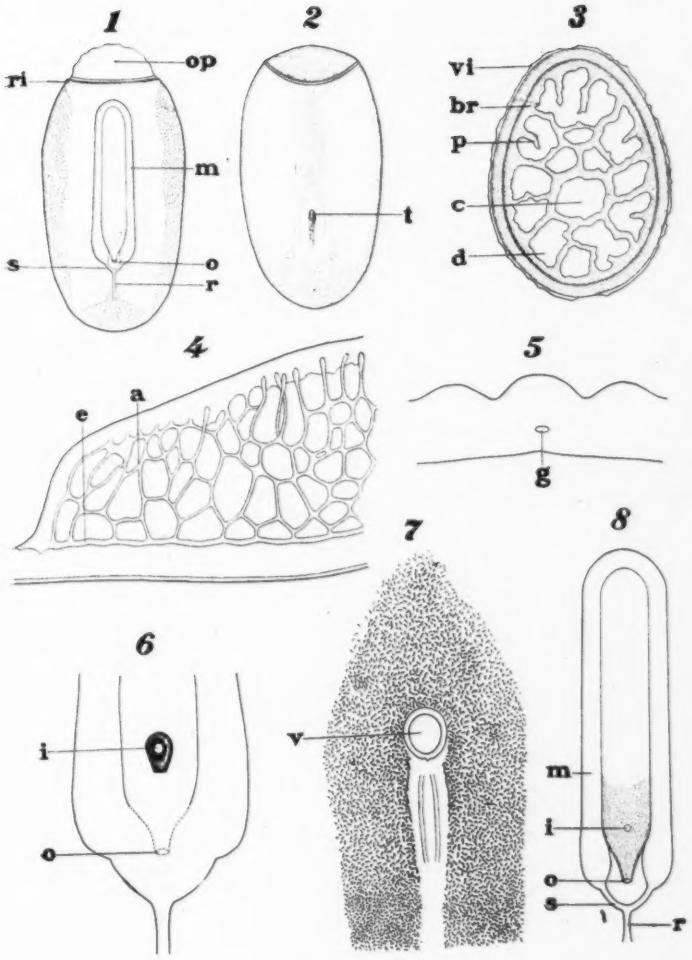
Fig. 4. Cross section of a part of the operculum: *e*, brownish upper surface of the floor of the operculum; *a*, chitinous deposits, between the floor and top of the operculum, resembling somewhat the thin-walled parenchyma of plant tissue except that no middle lamella is discernible.

Fig. 5. Cross section of the micropylar canal *g*, which is surrounded by extremely thick chitin. This canal opens to the exterior by the micropylar orifice.

Fig. 6. Posterior region of the inner surface of the "hilar area" of the chorion: *i*, opening of the micropylar canal in an invagination of the inner surface of the chorion; *o*, micropylar orifice.

Fig. 7. Vitelline membrane in the region of the micropylar apparatus: *v*, opening of the membranous tube, the vitelline membrane micropyle, into the vitelline membrane.

Fig. 8. "Hilar area" on the outer surface of the exochorion; lettering as in Figs. 1 and 6.



H. H. P. Severin.

A STRUCTURAL STUDY OF SOME CATERPILLARS.*

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Although the Lepidoptera have been studied for a long time little attention has been paid as yet to the minute description of their caterpillars. In describing a caterpillar most authors have contented themselves with the colors and markings, adding an occasional note on the structure if especially striking.

My problem, therefore, has been to discover external structures characteristic of the groups of caterpillars, especially such as have been less carefully studied by others. This paper then deals mainly with the parts and setae of the head. I have also summarized my studies on the prolegs, and have included some of Dyar's characters derived from the body-setae. I have tried so far as possible, to lay emphasis also on such characters as could be determined from the cast skin. It appears that, with a little care since they are brittle, the characters of the head can be made out quite as easily from cast skins as from killed material. The body can not be studied quite so well, but at least the arrangement of the proleg hooks, and also the type of vestiture, whether primary, secondary or tufted, can be made out without trouble.

Material and Methods.

My material is made up of specimens representing about 125 genera, preserved in various ways. The major part were collected personally in the course of the past summer and preserved in alcohol. There were also a few cast skins, and a few caterpillars dried whole without any preparation. To this I added a number of species from the American Entomological Company, which were preserved in formalin, and a series of inflations, mostly of Microlepidoptera, from Staudinger and Bang-Haas.

Most of my alcoholic material was cleared by boiling in 10 per cent. caustic soda, cutting the skin down one side, and separating the maxillae and labium from the rest of the head. The dried caterpillars were treated in the same way. Often one mandible was also removed to give a clearer view of the labrum. The prepared skins were then preserved in alcohol, except a few that

* A Dissertation submitted to the Faculty of Clark University, Worcester, Mass., in partial fulfillment of the requirements for the degree of Doctor of Philosophy, and accepted on the recommendation of C. F. Hodge.

were mounted in Farrant's gum-glycerine. The same method was tried on formaldehyde specimens, but with much less success, as the muscle would not dissolve easily and had to be picked out piecemeal.

The remainder of the specimens were examined entire, as opaque objects. By placing them in full sunlight, or even concentrating it on them with a lens, they could be examined successfully, even with rather high powers of the microscope. A binocular microscope was very useful, especially in getting a correct idea of the relations of parts, in dissecting, and in hunting for setae.

Inflations of the smaller species were sometimes immersed in xylol, or in absolute alcohol, when they could be examined by transmitted light. They did not collapse on being taken out and dried again.

Most of the drawings were sketched with the camera lucida, the details being put in free-hand under a higher power. They were not drawn to a single scale, as they differ a great deal in size, and the size is of little classificatory value.

The purchased specimens were received with names. In the case of the others, which were named by the writer, there was often some uncertainty, as indicated by question marks in the text. This was especially the case in the Noctuidae and Geometridae, where I have listed less than half of my specimens.

* * * * * * * *

I wish to express my thanks to the many who have made this study possible by their help in supplying specimens, in allowing the use of instruments and books and by advice and information.

Wm. T. M. Forbes.

STRUCTURE.

A caterpillar is an insect larva in which the thorax and abdomen are similar in general appearance, the head alone is heavily chitinized; there is no sclerite between the antennae and the mandibles; the mouthparts are small and largely retractile, with lacinia not recognizeable as such and no glossæ or paraglossæ. The whole structure of the maxillæ and labium is peculiar and not closely paralleled in other orders.

Most of the head as seen from in front, is composed of the two *epicrania* (compare Fig. 1), each of which usually bears eleven primary setae and the eyes. There are also almost always

present additional setae or punctures, mostly in the neighborhood of setae i and ii. (One pair of punctures is shown in the figure).*

Lying above the mouth and separating the epicrania is a triangular sclerite, the *front*. It has two setæ near its lower outer angles, and usually between them a pair of punctures. In *Hepialus*, however, the setæ lie between the punctures. The front and the epicrania are separated by a pair of narrow *adfrontal* sclerites, each of which has two setæ and a puncture between them.†

Bordering the lower side of the front is the *clypeus*, with a pair of setae at each end; and hanging from that, the movable labrum, which belongs functionally to the mouth. Its structure will be mentioned with that of the mouthparts.

On each side, between the two articulations of the mandible is the antenna. (Fig. 29.) It is four-jointed, but all but the second of these are minute. There is a large membranous cone at the base, which Scudder treats as a true joint. It is inverted when the antenna is retracted, and would seem to be no different from the membrane which separates all the joints of the antenna. The antenna is surprisingly constant in its structure, the arrangement of setæ shown in the figure occurs with little change in all the caterpillars studied. The Lasiocampidae alone have a few secondary setæ.

The mouth parts are the labrum, or upper lip (Fig. 12), the two mandibles (Fig. 28), and the lower lip (Fig. 2), which in caterpillars is formed of the maxillae as well as the labium. The *labrum* is oblong, wider than high, with the free edge rounded, and with a notch, through which the food is guided into the mouth. It bears (1) a row of four setæ across the top of the notch (i and ii), (2) two pair of setæ on the lateral edge (iii and iv), (3) two pair of setæ on the tip of its two lobes (v and vi). There are several punctures, the most noticeable of which is the one indicated in the drawing and marked *ia*. On the inner side there are a large number of sensory cones, and near the outer edge three larger similar cones. The latter are indicated in outline on the figure. The labrum has been especially useful in furnishing characters.

† The front, as the term used in this article, has been usually called the clypeus, the adfrontals being known as paracylpeals, and the clypeus as anteclypeus or epistoma. I believe that the set of names used here agrees better with their homologies in other orders.

* Dyar's numbering of the setae, which has been copied in Fig. 1, is published in Journ. of the N. Y. Entomological Society IV, 93, with a figure.

It varies considerably in the position of its setæ, and is flat, not easily distorted, and easily studied under the microscope. The setae which appear on the margin in figure 12 have often migrated inward a distance on the surface of the labrum, and in different groups it is different setae that have migrated. As is often the case these differences define smaller groups in the butterflies, than in the moths. For example, vi has migrated up toward ii in the Sphingidæ, in Apatelodes, which shows other resemblances to the Sphingidae also; and in a part only of the Nymphalinae among the butterflies. (Figs. 14 to 18). iii migrates inward in the Pierids. Another striking arrangement occurs in the Skippers, as shown by Figs. 23 and 24.

The *mandibles* are the heavy jaws, and are the only ones used for biting. They bear two setæ on the outer side and the edge is more or less notched, the notches of the two sides fitting into each other. Taxonomically they seem more characteristic of genera than of larger groups. The position of the distal seta far out on the scrobe, as shown in the figure, is typical of the Sphingidæ. The Arctiidæ show interesting variations in structure of the mandibles.

The *labium* forms the middle of the hind margin of the mouth. It is roughly cylindrical. The basal part is formed by a long, usually lightly-chitinized joint, the *mentum*, which bears two setae near its middle. Resting on that is the heavy ring-shaped sclerite, *a*, whose setæ are shown in the figure as free in the membrane distad of the sclerite. This is often the case. The tip of the labium is retractile, and therefore largely formed of membrane (see Fig. 3). Projecting from its center is the cylindrical or flattened spinneret, which is of membrane, strengthened by three chitinous bands. Surrounding the base of the spinneret is the ring, *c*, composed of an inner and an outer semicircular sclerite. It bears a puncture at each side, and may be either very wide and heavy as in the *Psychidae*, or reduced to a narrow ring about the puncture, as in typical *Noctuidae*. The *labial palpi* spring from an area of membrane on each side of *c*. There is one large and one minute joint, each bearing a seta. In Catocala there is also a rudimentary basal joint. The remaining sclerite, *b*, of the labium forms a semicircle about the base of the palp. It bears two punctures at its ventral end.

The *submentum* is divided into a pair of triangular sclerites at the base of the labium. These are usually separated by the base of the mentum. (Compare Figs. 2 and 25).

All the parts of the labium and maxillae are described as if looking at the exposed surface from below or from behind according to the position in which the caterpillar holds its head. This surface morphologically consists of the caudal aspect of the labium, and the caudo-lateral aspect of the maxillae.

The *maxillae* are fused at the base with the labium, but are free at the tip. The main part is made up of a usually lightly chitinized joint, the *stipes* (plus the palpifer) which bears two setae at its distal end. The *cardo* forms a small triangle between the base of the stipes and the submentum. At the tip of the stipes there are two very incomplete rings, which would seem to be the basal joints of the palpus, but which are completely fused with the maxilla proper. In Hepialus the more distal of these is shaped like a normal joint of the palpus, and in Micropteryx, according to Packard, it is free. From the end of these arises the two-jointed free part of the palpus, and mesad of this springs the large basal joint of the galea, which forms an incomplete ring. The tip of this joint bears the two maxillary lobes (which are the distal joints of the galea and lacinia?), and is also armed with two large cones (anterior to the maxillary lobes in Frenatæ, and mesad to them in Hepialus), two small cones (posterior to the maxillary lobes) and a step-cone between them. The latter is composed of a larger chitinous ring, bearing a thin-walled cone at its tip. Each of the maxillary lobes, also, bears a sense-cone at its tip.

Chitinous sclerites are but little developed as a rule on the body. The greatest development that I have seen on the abdomen occurs in Incurvaria. In this caterpillar each segment has two dorsal and two ventral plates (see Fig. 34). The anterior ventral plate, or *sternum*, extends between the prolegs.

The thorax has more extensive sclerites in *Adela*, as the sketch of the pro- and meso-thorax (Fig. 35) shows. Not many of the sutures are traceable, so that they can be only roughly homologized with those of other insects. The præsternum and sternellum of the prothorax are more distinct.

In higher caterpillars only the coxæ, which are divided by a clear suture into coxa and meron, are preserved. Besides the coxæ, the legs have very short femurs and tibiæ and a single-jointed tarsus, which bears one claw.

One of the chief characteristics of the caterpillars is the definite arrangement of setae. These are either primary, which

are common to all the caterpillars, and many of which can be homologized with setae occurring in the *Trichoptera* and *Panorpata;* or they are secondary, in larger numbers, and not definitely arranged. The setæ are more or less completely carried over into the pupa, with comparatively slight changes in their arrangement. Often in place of the primary hairs there are tufts of hair springing from the same wart. This is the condition spoken of as "with tufted hair." In such caterpillars as *Melalopha*, this is due to the occurrence of secondary hair on the tubercle of the primary hair, which remains quite distinct, but in the *Arctiidae* it seems rather to be a reduplication of the primary hair.

Where the secondary hairs are very few, like the primaries, they take definite positions, and are then known as subprimaries.

The arrangement of the primary setæ on the meso- and metathorax of the typical Frenatæ is shown in figure 4, while different arrangements for the abdomen are shown in Figures 5, 33 and 34. The small primaries numbered *iiia*, *ix* and *x* are usually overlooked. The numbering of the others is after Dyar, except that figure 33 is changed to make it agree with the others.

The prothorax has its arrangement modified by the persistence of three sclerites, the *cervical shield*, with many setæ and some punctures, the *prespiracular wart*, with two or three setæ (sometimes fused with the cervical shield) and the *subventral wart*, with two or three setae.

Tufted or secondary hair on the body is usually accompanied by secondary hair on the true legs and head. It reaches its greatest development in the Lasiocampidae, where it occurs even on the antennae and palpi, and on the sclerites, *a*, *b*, and *c* of the labium.

PROLEGS.

One may take as a typical proleg that of the *Tortricidae* or higher *Tineidae*. It is a fleshy, more or less conical projection, the tip of which, the *planta*, is more or less retractile, and rounded or flat. Around the edge of the planta is a series of hooks or crotchets, each imbedded about two-thirds its length in the skin, but with the tip free and hooked toward the center of the circle. To the center of the planta is attached a muscle, by which it can be completely inverted, even the hooks disappearing from sight. Just above the hooks on the outer side there may be a horny edge, and above that, a larger plate bearing three setae (vii). On the front of the base is a minute seta (sometimes entirely in front of the leg,) and on the inner side another (viii).

The possibly primitive state of the proleg can perhaps be reconstructed from Adela and Incurvaria. Each segment bore on the ventral side two chitinous sclerites, between which was a fold of membrane, which was rough with minute conical granulations like the rest of the skin. In this membrane there may have developed a concave fold, which lost its granulations, while those at each edge of it were enlarged, and became regularly imbricated, gradually becoming like the unmodified granules as you go away from the fold toward the two sclerites. This is the condition of Adela, (Fig. 6), except that the sclerites still preserved in Incurvaria, are lost. On segment A6 the front side of the fold only develops hooks, and the folds of the remaining abdominal segments (1, 2, 7, 8, and 9) are traceable, but entirely without hooks. There are no anal legs.

In Incurvaria (Fig. 7) the posterior rows of hooks have disappeared on all the segments, so that A6 is no longer different from A3 to 5, and the hooks are reduced to a single row.

Hepialus has kept two rows of hooks, and in part, three, but the terminal row is much more highly developed, while the others are quite rudimentary. The two bands have fused on the inner side, and approach each other on the outer side, thus enclosing the fold, which becomes the planta. In many higher micros the outer ends have also fused, making the circle (ellipse) complete. In all above the Tineidae there have developed hooks on the last segment, but there is never a posterior series, or a complete circle; in some there is a straight band, which becomes a loop, but is always open posteriorly. It is nearest a circle in the Psychidae and lower butterflies. In the higher forms (butterflies and Noctuidae for instance), it has again become straight, but longitudinal, by the disappearance of the outer hooks.

The ventral legs have a similar evolution. The circle which serves as a type for all the higher species may be broken on the outer side (*Pyralididae*), on the inner side (*Psychidae*), or on both (*Ægeriidæ*). It may be broken in front and back (*Papilionidae, Thyatiridae, Libytheidae,*) and in that case the outer half becomes weaker, and then disappears, leaving an inner band only (*Noctuina, Bombycina*, higher butterflies, etc.)

In the *Tineina* the last ventral legs may entirely disappear (as has been mentioned they are only half developed in the very primitive type Adela) while in several higher families the first ventrals are lost (*Noctuidae, Geometridae, Nolidae*). In the

Thyatiridae, *Drepanidae* and *Notodontidae* the last legs either disappear or are modified, while in the lowest Tineids they may have never developed (Adela, Incurvaria). In the *Eucleidae* and *Nepticula*, as well as some other leaf-miners there are no hooks at all on the prolegs, but the area of roughened skin in Nepticula suggests an even more primitive condition than occurs in Adela.

The *Lycaenidae*, as well shown in Scudder's figure, have developed an outer fleshy lobe, apparently from the planta. The planta is apt to be unrecognizable in those which have lost the outer part of the circle of hooks, but its retractor muscle serves as in the lower ones to withdraw the hooks that remain. (Compare Jasoniades with Papilio).

In Lagoa the line of hooks is sharply angulate at the middle and there the hooks are shortened.

Another variation is in the arrangement of the hooks in the band. In the most primitive forms all those in a single line are of equal length gradually decreasing to the end, but a little higher in the scale, there develops an alternation of length by which the hooked tips are thrown into two or more ranks. In many of the highest families the single length again prevails, apparently as a secondary modification. In the lower forms (Micros) these two arrangements intergrade, but in the Macros they separate families or even superfamilies very sharply.

The proleg typically bears four setae, three on the outer side (vii) and one on the inner or anterior side (viii). The minute primary ix may migrate up on to the anterior side.

HOMOLOGIES AND NAMES OF THE PARTS OF THE HEAD.

About the identity of the front and clypeus; and of course of the mandibles, labrum, maxillae and labium as a whole, there can be little or no doubt. The epicrania, as the name is used in this paper, include also a number of other sclerites which are fused with it so completely as to show no suture. A large part of the epicrania becomes the compound eyes in the imago. The postgenæ will not be discussed to any extent, but they are quite distinct.

The naming of the parts of the maxillæ and labium on the other hand has been done mainly in order to refer to them intelligibly. Such grounds as I have for this tentative homologizing may be largely drawn from the figure of the Elaterid beetle larva,

figure 25. The arrangement is about the same in Phryganea (one of the herbivorous caddis-flies), but in a sawfly, as shown in figure 32, there is no close relation to the others, the modifications having taken quite a different direction. In all three of these non-lepidopterous types the lacinia of the maxilla is well developed, but in the Elater the proximal joint of the galea is open on the inner side, and one can see how the lacinia might easily fuse to it in much the same way as the galea is fused to the two basal joints of the palpus in the higher caterpillars.

Especially striking is the complete disappearance of the glossæ and paraglossæ, not only in the larvæ figured, but in the adult Elater also. The setae marked *ai* and the more ventral of the two sclerites which form the ring *c*, come closest to the normal position of the glossæ and paraglossæ.

ARTIFICIAL KEY TO THE FAMILIES OF FRENATÆ.

(Incomplete in the Microlepidoptera.)

1. Prolegs each of one or two transverse bands of rudimentary hooks, no anal prolegs ..... **Tineidae**
1. Hooks of prolegs in curved or longitudinal bands, or in a circle, anal prolegs wanting only in Drepanidae 3
1. No prolegs, or prolegs without hooks 2

2. Slug-caterpillars, exposed feeders ..... **Eucleidae**
2. Slender leaf-miners ..... **Nepticula** and other **Tineina.**

3. Hooks of prolegs in two curved transverse bands ..... **Ægeriidae**
3. Hooks of prolegs in a complete circle or horseshoe 4
3. Hooks of prolegs in a longitudinal band, on inner side of leg, with or without a rudimentary outer series 8

4. With much fine secondary hair 5
4. With a single subprimary on the proleg ..... **Lacosomidae**
4. Without secondary hair 6

5. Head much larger than second segment ..... **Hesperiidae**
5. Head smaller than second segment ..... **Megathymidae**

6. Circle of hooks interrupted caudo-mesally, and as complete on anals as on the other prolegs ..... **Psychidae** 7
6. Circle of hooks complete, or interrupted outwardly, anal prolegs with a shorter, straight or curved band.
The typical Micros, including **Cossidae, Thyrididae** and **Orneodidae.**

7. Seta i of abdomen dorsal of ii, front much higher than wide ..... **Solenobiinae**
7. Seta ii of abdomen dorsal of i, front as wide as high ..... **Psychinae**

8. Hooks of prolegs alternately of three lengths, at least with some short hooks on anal prolegs ..... **Papilionina** 9
8. Hooks of prolegs alternately of two lengths 21
8. Hooks of prolegs of the same length, or gradually growing shorter to the end of the rows 12

9. Maxillary lobes minute; labrum with 18 or more secondaries ..... **Papilionidae**
9. Maxillary lobes at least half as long as terminal joint of palpus; labrum with less than 18 secondaries 10

10. Slugcaterpillars with small heads ..... **Lycænidae**
10. Normal cylindrical caterpillars 11

11. Seta iii of labrum as near to ii as to iv, far from margin.....**Pieridae**
11. Seta iii of labrum on margin.....**Nymphalidae**

12. Hooks of prolegs in an angulated band, shortest at the angle; with additional prolegs (two pair) without hooks.....**Megalopygidae.**
12. Hooks of prolegs in a straight or curved band; no additional prolegs...13

13. Anal prolegs reduced or modified, with fewer or no hooks..**Notodontidae**
13. Anal prolegs larger than ventral ones.....14

14. With dense fine secondary hair on head, body with tufted hair.....15
14. With some sparse secondary hair on head, body with tufted hair..**Arctiidae**
14. Without secondary hair on head, body often without secondary or tufted hair.....17

15. Eversible dorsal glands on posterior abdominal segments; a tuft of secondary hair on the adfrontals; five warts on mesothorax.....**Liparidae**
15. No eversible dorsal glands; no such tuft of secondary hair.....16

16. Three warts on mesothorax, the upper very large.....**Syntomidae**
16. Four nearly equal warts on mesothorax.....**Noctuidae (Pantheinae)**

17. Body with primary hair only.....**Noctuidae**
17. Body with tufted or secondary hair.....18

18. Fourteen legs (first prolegs wanting).....**Nolidae**
18. Sixteen legs.....19

19. Two warts above spiracle on each segment of abdomen.....**Zygaenidae (Pyromorphidæ)**
19. Three warts above spiracle on each segment of abdomen, or with secondary hair.....20

20. Adfrontal puncture three times as far from lower as from upper seta..**Arctiidae**
20. Adfrontal puncture not more than twice as far from lower as from upper seta.....**Noctuidae (Acronyctinae)**

21. Without secondary hair.....22
21. With dense fine secondary hair (often minute).....23

22. Anal legs wanting; a series of small outer hooks on prolegs..**Drepanidae**
22. Anal legs reduced; a few outer hooks on prolegs.....**Thyatiridæ**
22. Anal legs large; ventral prolegs reduced or wanting; no outer hooks on prolegs.....**Geometridae**

23. Secondary hair on antennae, palpi, and sclerites a, b and c of labium **Lasiocampidae**
23. No secondary hair on antennae, palpi, or tip of labium.....24

24. Seta vi of labrum distant from margin, migrated toward ii*.....25
24. Seta vi of labrum marginal or nearly so.....26

25. Hair microscopic; without tufted hair.....**Sphingidae**
25. Hair conspicuous; with tufted as well as secondary hair....**Apatelodes**†

26. An unpaired dorsal spine or tubercle on ninth abdominal segment **Citheroniidae**
26. Usually with an unpaired dorsal spine on eighth abdominal segment, but never with one on the ninth.....**Saturniidae**

* This separation does not entirely hold, see the descriptions of the individual families.
† Probably does not belong to the Notodontidae.

SPECIAL PART.

THE SUBORDERS.

JUGATAE: Unfortunately I have only the highest family, Hepialidae, of this suborder for examination. Probably the head characters will hold in the other families, so far as they are primitive in their nature, such as the palpi, ocelli and galea, but the others will be very likely to fail.

Frontal punctures more widely separated than frontal setae; the four anterior eyes arranged in two pairs; galea with the area of membrane on the mesal aspect, one of the large cones being shifted far proximad on that side; second joint of palpi more distinct than in the Frenatae and shaped like the free distal ones; an anterior subdorsal seta present on the meso- and metathorax, besides the minute primaries; iiia of abdomen large and dorsal to iii; ix of abdomen large, on leg-base.

The abdominal setae iv, v and vi of Hepialus hectus are arranged very much as in Incurvaria. The hooks of the prolegs form a circle broken shortly on the inner side; they are all of one length, but there is a double series of rudimentary hooks at their base.

Figures 27, 30, 33.

FRENATAE (including Rhopalocera): Frontal punctures closer together than frontal setæ; the four anterior eyes forming an arc of a circle; base of galea with the area of membrane on the anterior side, and with the large cones nearly opposite the maxillary lobes; first two joints of palpi quite similar, very short, and completely fused into the maxillae; no anterior subdorsal seta on thorax (except in Lithosiidae, which are otherwise very highly developed Frenatae); iiia of abdomen minute, usually lying between iii and the spiracle; ix of abdomen minute.

The prolegs of Adela are probably more primitive than those of Hepialus.

SUPERFAMILY PAPILIONINA (including the Hesperiina):*

Prolegs with hooks alternately of three, very rarely of two, lengths, either in a complete circle or a straight line. Secondary hair present (on body, epicrania, front, mandibles and stipes, and sometimes everywhere except on the tips of the mouthparts and the antennae.) Labium narrower than the maxillae, and narrower at the base than one of the submenta.

* See Scudder, Butterflies of Eastern North America; for a good many additional characters, and for descriptions of all the known eastern species.

Of the Hesperiina I have seen no caterpillars of the Megathymidæ. The characters I have italicized should be expected to apply to them as well as the Hesperiidæ, while the small, normal head will separate them.

1. Labrum very shallowly notched, all six setae near the outer edge; cervical region chitinized in two pair of sclerites, which fuse more or less to the corresponding sclerites of the head; postgenae very wide. Large cones with a tuft of branches (unique). *Prolegs with hooks in a complete circle,* or *shortly broken on the outer side;* part of primaries modified into flat plates, the others inconspicuous. *Labial setae ai close together.* *Hesperiina, Hesperiinae*

* Feet with 125 hooks, alternately of 3 lengths. Head square; postgenae with setae; adfrontals abruptly widened at top of front; gula as wide at base as it is long. Example: *Epargyreus tityrus* (Fig. 23).

* Feet with 50 hooks, alternately of two lengths; head heart-shaped; postgenae fused with gula and without setae; adfrontals very wide and long; gula twice as wide. Example: *Pholisora catullus.* (Fig. 24).

1. Labrum usually with setae normal (about as in Noctuidae) not all on the terminal margin, usually moderately notched; cervical region not chitinized, postgenae meeting, or else very narrow. Large cones simple, normal. Proleg with hooks never in a complete circle or horse-shoe (the outer band preserved only in Jasoniades, Euphoeades) primaries unmodified, usually similar to secondaries; labial setae *ai* widely separated. *Papilionina* go to 2.

2. Labrum with about 18 secondaries. Maxillary lobes very small, front wider than high, not reaching half way to vertex; clypeus as broad as 1-3 height of front, with many scattered secondaries, primaries separated by half the distance that separates the two primaries i from each other. Lower end of adf. about as broad as clypeus. *Papilionidae*

* Feet with an outer row of 45 small hooks and an inner row of 80 large ones. Example: *Jasoniades glaucus* (Figs. 11 and 22.) *Euphoeades troilus.*

* Feet with a single row only of about 50 hooks. Example: *Papilio polyxenes* (Figs. 10 and 21.) *Laërtias philenor.*

2. Labrum with less, or usually without secondaries. Maxillary lobes at least half as long as last joint of palpus. Front higher than wide (except in Anosia) usually reaching more than half way to vertex; clypeus usually much narrower, and with less or no secondaries, when widest the adfrontals are only about half as wide as it at the bottom. go to 3.

3. Head small and body stout; prolegs with fleshy outer lobes curving down over the row of hooks; clypeal setae very far apart; about as in Papilio, but on a narrow clypeus. Seta iv of labrum some distance from the margin. Adfrontals apparently very narrow. *Lycaenidae* Example: *Thecla ilicis.* (Fig. 38.)

3. Head at least half diameter of body, which is approximately cylindrical; prolegs normal; seta iv of labrum variable. Claws of true legs deeply lobed. go to 4.

4. Primaries on body mostly distinct, in *P. brassicae* conspicuous; adfrontals very narrow; clypeal setae far apart; iii of labrum distant from margin nearly as far as from seta ii. *Pieridae* Example: *P. rapae,* (Fig. 20), *P. brassicae.*

4. Primaries on body not distinguishable from secondaries, at most a little larger; adfrontals about 1-5 as wide as height of front; clypeal setae separated by a distance not more than ½ that between the two setae i; iii of labrum close to margin. *Nymphalidae*

5. Prolegs with outer hooks (4 scattered ones); segments of abdomen divided into four equal annulets, each bearing a row of larger black setae. *Libytheinae* Example: *L. celtis.* (Fig. 37.)

5. Prolegs with the inner row of hooks only; one annulet of each segment broad; the larger black setae, if present, irregularly arranged, or on spines. go to 6.

6. Front broad and epicrania high (as in Papilio) labrum with secondary setae; mentum only 1-4 as wide as stipes. *Euploeinae*
Example: *Anosia plexippus* (Fig. 12).

6. Front much higher than broad, and usually reaching more than half way to vertex; labrum with very few or no secondary setae; mentum wider. go to 7.

7. Labrum with i and ii low down near margin, and notch very shallow; mentum without secondaries; two minute points projecting back from rear of body, but otherwise unarmed. *Satyrinae*
Example: *Cercyonis alope.* (Fig. 19).

7. Labrum normal, with moderate notch, setae all about equal and i and ii far above the level of v and vi; mentum with secondaries (only one odd one in my specimen of Euphydryas phaeton). Body more generally spined, (or else entirely unarmed, in Anaea). *Nymphalinae*
Examples: *Argynnis cybele.* *Argynnini* (Fig. 14).
Euphydryas phaeton. *Melitaeini* (Fig. 15).
Polygonia interrogationis. *Vanessini* (Fig. 16).
Euvanessa antiopa. *Vanessini* (Fig. 17).
Basilarchia disippus. *Nymphalini* (Figs. 18 & 36).

Spines very unequal in Basilarchia.
No unpaired spines in Basilarchia, Argynnis.
Two unpaired spines on last segment in Euphydryas.
Two spines to a segment in subventral row in Euphydryas.
Hooks of prolegs less regularly arranged in Basilarchia.
Ventral legs with hooks of two lengths only in Euphydryas, of four lengths in Polygonia.
30 hooks in Euphydryas, 50 in Vasessini, 60 in Basilarchia.
Clypeus and adf without secondary setae in Basilarchia.
Mentum with most setae in Euvanessa.
Postgena wider in Euvanessa.
Labrum with secondary setae in Argynnis.

THE SPECIALIZED MACROFRENATÆ.

Following the Butterflies there comes a series of families which include the larger and better-known moths. These may be divided for convenience into two groups, which perhaps represent very early-separated lines of descent.

The first group, which seems to be especially associated with a tree habitat, may be roughly defined by the presence of four setae on the outer side of the legplate (the upper one of which will be spoken of in this article as *vib*), by the usually rather small front and large epicrania, and especially by the hooks of the prolegs, which are alternately of two lengths. The caterpillar very frequently has secondary hair, obscuring the arrangement of the primaries; and the imago shows a very strong tendency to lose the frenulum. (It is minute or wanting in the Saturniidae, Ceratocampidae, Lasiocampidae, Endromidae, Bombycidae, Drepanidae and Lacosomidae, also in a few Sphingidae and Geometridae). Most of the families are small, and the type, except as

represented by the Geometridae, seems to be geologically past its prime.

On the other hand the group typified by the Noctuidae is the dominant modern type of moths. Though they are much more uniform in adult structure, there is a vast number of species, and a surprising variety of larval types. In these families the outer side of the leg-base never has more than the three typical setae of *vii* unless tufted hair is present. There is never but one length of hooks on the prolegs; the front is usually somewhat larger in proportion. Secondary hair is very rare, occurring only in Thaumetopœa, Panthea and Apatela, and only in some species of the latter. A decided majority of the species live on low plants.

GROUP I. (*with vib, and usually with secondary hair*).

This group again can be divided for convenience into two sections, those with and those without secondary hair. The first includes the Sphingidae, Saturniidae, Bombycidae, Lasiocampidae and related families: the second, the Notodontidae, Thyatiridae, Drepanidae, Geometridae, and Lacosomidae, doubtless also the Epiplemidae and Dioptidae.

The Notodontidae have been an especially puzzling group. Apatelodes shows no distinct affinity to the others, but is in every traceable way more like the Bombycidae and Saturniidae. In hairiness it surpasses both, and approaches the Lasiocampidae. The single-haired Notodontidae (such as Cerura and Heterocampa) show seta *vib* unmistakably. Datana has secondary hair on the body, and in Melalopha it has invaded the head and the tubercles, producing a kind of tufted hair in which the primaries still remain dominant. The distribution of hair on the head is quite different from that of Apatelodes, with which the moth has been associated. In most ways it would seem more natural to derive the series from the Thyatiridae, and consider such genera as Gluphisia and Nadata, primitive. Still the hairy prolegs of Gluphisia* and Nadata would point toward an origin from the series with secondary hair. In the latter case the primitive Notodontan must have had very nearly the structure of Melalopha, with a recessive tendency to have a seta *vib*.

Lacosoma is a synthetic form between the rest of the series and the Microlepidoptera, with positive relations to both, as will be discussed under the heading of its family.

* See Packard's figure, Monog. Bombyc. I. Pl. Fig.

SPHINGIDAE.

Minute secondary hair on epicrania, front, adfrontals, maxillae, labium and body; none on clypeus, labrum, mandibles, or distal parts of maxillæ and labium; primary hairs *iii* and *iv* of abdomen usually distinct (directly above and below the spiracle), *i*, *ii* and *iii* of epicrania also sometimes distinct, never with tufted hair or branching spines. Epicrania large, extending more than the height of the front above its top, usually much more. *ii* of adfrontals about at their middle (they are usually the lowest setae the adfrontals bear); labrum with *vi* decidedly more distant from the margin than *v*, *iii* and *iv* not very close together; mandible with one seta far out near tip of scrobe; mentum very wide at base, without distinct submenta; prolegs with a single band of hooks alternately of two lengths, the anal prolegs the largest; caudal horn present except in Ellema.

SESIINAE: Primaries i, ii and iii of epicrania easily recognized by their enlarged punctures; lower ocellus rather farther than usual from the others; front wider than high, its width nearly half as great as height of head; adfrontals very narrow and with very irregular outer margin; clypeus very narrow, the setae close together, separated by only about 1-7 the distance between the two setae *i;* head setae black and conspicuous under a lens; labrum with setae *i* and *ii* in a straight line, *iii* farther from the margin than *iv*, *vi* distant from the margin only about 1-6 of height of labrum, notch shallow; two conical spines on anal plate.*

Example **Pseudosphinx tetrio,** Figs. 47 and 50.

(The remaining subfamilies have primaries of epicrania rarely distinct, front usually higher than wide, adfrontals wider, clypeus usually wider, especially at the two ends, with the setae of each pair farther apart, head setæ colorless, labrum with setæ *i* and *ii* out of line, *iii* often as near the margin as *iv*, *vi* usually much higher, and the notch much deeper, anal plate unarmed).

ACHERONTIINAE (Sphingicae only were examined). Head higher than wide, rather regularly rounded, or moderately tapering toward the vertex, a large number of very minute setæ on the epicrania, averaging eight or ten in a portion of the epicrania the size of the front, arising from depressions on the surface, front with very sinuous margins, labrum deeply notched; skin usually smooth in last stage; horn always normal.

Body rough and granular, four short soft horns on thorax; two oblique lines of granules on each segment besides the mid-dorsal line; labrum with v distant from margin; mandible with teeth less distinct than usual in the family; posterior ocellus rather high, front only 1-3 height of head and with exceptionally sinuous outer margin; head distinctly tapering toward vertex, widest near base.

Example **Ceratomia amyntor** Figs. 45 and 49.

Widest point of head about halfway up; front proportionately very wide toward the apex. Horn at the middle about as thick as at base. Posterior ocellus a little lower; front about two-fifths height of head.

Example **Sphinx gordius.**

* Hemaris is less aberrant.

Head decidedly tapering upward, upper part of front narrow, horn tapering regularly; otherwise about as in Sphinx.
Example **Dolba hylaeus** Figs. 39–41.

Labrum much less deeply notched, head intermediate between that of gordius and hylaeus; front hardly more sinuous than in Deilephila. Horn strongly curved and regularly tapering.
Examples **Phlegethontius celeus.**
P. sexta. Fig. 51.

AMBULICINAE: Head much higher than wide and tapering much to the vertex; epicrania with only three or four setae in an area the size of the front, set on decided tubercles; front with margins sinuous as in the preceding subfamily, quite small proportionately; Labrum very deeply notched. Skin rough, horn always conical, variable in size.

Example **Paonias myops** Figs. 42–44.

PHILAMPELINAE: Head squarish; front small in proportion to head, and higher than wide; with much straighter margins than in the preceding groups; posterior ocellus low, as near to lower ocellus as to the fourth one; labrum deeply notched; a subspiracular ridge on the anterior segments, disturbing the incisure between thorax and abdomen; skin always smooth, horn variable.

Head wider than high, third ocellus much enlarged; caudal horn shorter than height of head; supraanal plate nearly an equilateral triangle, and acute at tip.
Example **Amphion nessus.** Figs. 48 and 53.

Head higher than wide, with the sides nearly parallel; third ocellus much enlarged, caudal horn nearly normal; supraanal plate as narrow as in the last, but with the tip rounded off.
Example **Darapsa myron.**

Head higher than wide, the sides converging somewhat toward the vertex, caudal horn replaced by a low button; supraanal plate broad and rounded.
Example **Pholus pandorus.**

CHŒROCAMPINÆ: Head decidedly wider than high, the upper part nearly spherical; epicranial seta *ii* distinct; posterior ocellus high, half farther from lower than from fourth ocellus; front wider than high, its width equal to about half height of head, its margins nearly straight, as in the last subfamily; clypeus quite narrow with the setae close together as in the Sesiinae; labrum with notch shallow; *i* and *ii* nearly in a straight line; *iii* farther from the margin than *iv*; *vi* not very far from the margin. This comes nearer than any of the others to Pseudosphinx.

Example **Deilephila gallii** Figs. 46 and 52.

APATELODES.

Secondary hair on epicrania, front, adfrontals, mandibles, maxillae, labium and body, but not on distal parts of maxillae and labium or on clypeus or labrum; tufted hair also on body. Front rather large, the epicrania extending about its height above it, labrum with setae *vi* quite distant from margin, *iii* and *v* also not marginal. Secondary setae of labium arranged in two diverging rows. Setae *ai* of labium close together. Prolegs with hooks in a single band, alternately of

two lengths. No caudal horn. Frontal punctures close together, but the setae *i* are also close together. Mentum somewhat wider at the base than one of the submenta.

It may be distinguished from the Saturniidae by the much denser hair on the maxillae, the larger front and the fact that setae *a i* of the labium are much closer together. This genus is entirely isolated in the North American fauna, it is perhaps most often placed with the exotic family *Eupterotidae*.

Examples **A. torrefacta** Figs. 54, 55 and 56.
A. angelica.

Lasiocampidae.

Very dense secondary hair on all parts except the tips of the palpi, even on the antennae; tufts also present (*i, iii, iv* and *vii*), but reduced; front rather small, the punctures close together, and the primary setae rather close together; adfrontals enlarged opposite top of front, with the setae close together. Prolegs with hooks alternately of two lengths in a single row.

Second joint of antenna three times as long as wide. Labrum with most of the secondary hair toward the tip of the lobes; prolegs spread laterally; a low tubercle in place of caudal horn; lappets on legless segments simulating the legs, also on first segment each side of the head.
Example **Artace punctistriga** ?.

Second joint of antenna twice as long as wide, labrum with most of the secondary hair in the neighborhood of setae i and ii; no lappets or tubercles, prolegs normally placed.
Examples **Malacosoma americana.**
M. disstria (Figs. 59 and 60).

Saturniina.

Secondary hair on epicrania, front and body, and sometimes on adfrontals, mandibles, maxillae, and labium; tubercles, at least in part with tufted hair; tubercles *ii* of either eighth or ninth abdominal segments fused across the middle line (that of the eighth would be the caudal horn), except in Saturnia; mentum wide, its base wider than one of the submenta; prolegs with hooks alternately of two lengths, in a single band; setae *ai* of labium far apart; punctures of front far apart, with reference to the setæ, but close together in comparison to the width of the front.

Ceratocampidae: Tubercles ii of ninth abdominal segment fused.

Adfrontals, maxillæ and labium without secondary hair; front as wide as high and head wide; *ii* of adfrontals about 2-5 up the front; clypeal setæ close together; secondary hair of body minute; armed with many long horns.
Example **Citheronia.** Fig. 63.

Maxillæ with secondary hair but none on adfrontals; front wider than high, *ii* of adfrontals only 1-3 way up it; clypeal setae close together; head as wide as high; secondary hair of body long.
Example **Basilona.** Figs. 61 and 65.

Maxillæ, adfrontals and labium with secondary hair; head and front both higher than wide; adfrontals wider; both *v* and *vi* of labrum distant from margin; secondary hair of body minute.
Example **Anisota.** Figs. 62 and 64.

SATURNIIDAE: Tubercles of ninth abdominal segment separate.

Labrum notched about half its depth; adfrontals without secondary hair, the puncture very close to the upper seta; secondary hair of labium in two parallel rows, (as in Apatelodes) secondary hair also on maxilla, but not on labrum or mandible; maxillary lobes well developed, decidedly longer than broad.

Hyperchiria io. Figs. 66 to 68.

Labium with not more than one or two secondaries; mandible with secondary hair; maxillary lobes minute; labrum cleft two thirds its width or more; adfrontals with several secondary hairs.

Labrum with secondary hairs; warts of body larger, several haired.

Example **Telea polyphemus.** Fig. 69 and 70.

Labrum and warts with primary hair, warts smaller.

Example **Tropaea luna.** Figs. 71 and 72.

(The labrum in this figure is aberrant).

GYNANISA ISIS agrees structurally with this family.

ENDROMIDAE.

With secondary hair on epicrania, front, maxillae and body, but none on adfrontals, clypeus, labrum, mandible, labium, etc.; hair minute. Epicrania large and front small, higher than wide, punctures of front far apart and lower than setae; labrum deeply notched, seta *vi* a short distance from the margin, *iii*, *iv* and *v* close to the margin; mentum not very wide, about as wide at the base as one of the submenta; upper ocellus minute; prolegs with hooks in a single row, alternately of two lengths, anal legs larger than the ventrals. There are no North American species of this family.

Example **Endromis versicolor.** Fig. 57.

BOMBYCIDAE.

With secondary hair on epicrania, front, and body, and with one each (in the specimen before me) on adfrontals and maxillae, hair minute, but denser and longer than in Endromis. Tufted hair represented in adult by a single rudimentary tuft in the subventral region. Punctures, etc., about as in the Sphingidae and Saturnoidea; setae *ai* of labium moderately far apart, but not so far as in Saturniina. Basal joint (the one fused to the maxilla) of maxillary palp unusually broad. Prolegs with a single row of hooks, alternately of two lengths. Caudal horn present. There are no North American Species of this family.

Example **Bombyx mori.** Fig. 58.

NOTODONTIDAE.

Head with secondary hair, only in Melalopha; body with or without general secondary hair, but always with it on the prolegs; seta *vib* distinct unless covered by secondary hair; epicrania with setae *ii* well above the top of the front; submenta large and nearly meeting; frontal punctures farther apart than in most Noctuidae, often close to the setæ, front small, the head extending twice its height above its top; prolegs with hooks in a single band, not alternately of two lengths; anal prolegs reduced or modified, with fewer hooks; primary setæ distinct, arranged as in the Noctuidae, often on enlarged tubercles. For superficial structural characters in this family see Packard's Monograph of the Bombycine Moths, Part I.

MELALOPHINAE: With dense secondary hair on epicrania, front, adfrontals and body, also on the tubercles, but not obscuring the primary hair; notch of labrum shallow, the setae *i* and *ii* not far out of a straight line; anal legs moderately reduced.

Example **Melalopha apicalis.** Figs. 76 and 83.

PYGÆRINAE: Head without secondary hair; dense secondary hair on body, usually not obscuring the primary hair; epicranial setae *ii* three times as far apart as *i;* anal legs are rudimentary stemapods, with one or two retracted hooks, labrum small proportionately.

Examples **Datana ministra.** Fig. 78.
D. integerrima. Fig. 73.

NOTODONTINAE: Without secondary hair except on prolegs; anal legs well developed in one form or another (in the species studied fairly normal), with hair about as on the other legs; epicranial setae *ii* very high up; and little if any farther apart than *i;* anal dungforks not developed.

Labrum half as high as wide, cleft about half its height. Frontal punctures close to setæ.

Examples **Schizura concinna.** Fig. 74.
S. badia.
S. unicornis.

Labrum very high and deeply cleft; frontal punctures about trisecting the space between the setae; anal legs rather more reduced.

Example **Nadata gibbosa.**

Labrum and frontal punctures similar; anal legs very little reduced.

Example **Lophodonta.**

Frontal punctures close to setae: anal legs a little longer and more conical.

Example **Heterocampa guttivitta.** Figs. 80 to 82.

CERURINAE: Anal legs modified into stemapoda without hooks and with a retractile lash, with many setae; no secondary hair except on the stemapoda and prolegs; epicranial setae *ii* intermediate in position; anal dung-forks strongly developed. Labrum moderately notched.

Example **Cerura.** Figs. 75 and 77.

Family THYATIRIDAE.

Prolegs with a band of inner hooks, alternately of two lengths, and with a few minute outer hooks; anal legs slightly reduced; *vib* present but without other subprimaries; epicrania decidedly wider than high, front small; adfrontals wide, with *ii* low down, frontal punctures close; labrum with *vi* slightly up from margin, and very deeply notched. Mentum rather short, but submenta nearly meet in the middle line.

Head about a fourth wider than high; a slight hump on segment A8; body with a regular pattern of marks.

Example **Habrosyne derasa.**

Head about half wider than high; body entirely lacking any hump, and entirely without marks, setae less distinct than in Habrosyne.

Example **Bombycia or.** Fig. 88.

Family DREPANIDAE.

Prolegs with a band of inner hooks, alternately of two lengths, and with a short band of rudimentary outer hooks; no anal legs; a subpri-

mary hair near *iii*, and from two to four in a longitudinal line between *iv* and *v*, and *vii* (*vib*): head sometimes with subprimaries, but without secondary hair; epicrania high, and head higher than wide; supraanal plate with a median horn bearing two setae at its tip; adfrontals high with *ii* near top of front; mentum short and broad, but apparently with the submenta nearly meeting; labrum with *vi* a little distance from the margin.

Three or four subprimaries on head, four setae represent *vib*; granulations long and setiform, giving an appearance of fine secondary hair; subdorsal tubercles large, and present on meso- and metathorax (*ib*), and on segment 2 of abdomen (*ii*); labral notch somewhat shallower.

Examples **Drepana falcataria.**
D. arcuata. Figs. 89 to 92.

Less subprimaries on head, two setae represent *vib* on abdomen; granulations minute and conical; subdorsal enlarged tubercles smaller on thorax, and wanting on abdomen. Labral notch very deep.

Example **Cilix glaucata.**

GEOMETRIDAE.

No secondary hair, except occasionally on prolegs; at least one subprimary subventrally, often several; prolegs with hooks usually alternately of two lengths, the series often interrupted in the middle; (see Fig. 87). Epicrania full and rounded, or with the region of seta *i* produced into an angle; front large, the punctures rather closer together than the distance between a puncture and the corresponding seta; adfrontals narrow over the top of the front; clypeus and labrum normal; mandibles usually rather thin, with sharp teeth and setae close together; maxillae and labium normal, of about equal width, the mentum at the base decidedly narrower than one of the submenta.

The number of secondary setae on the proleg varies; in Cosymbia only the subprimary *vib* is present; in Alsophila and an unidentified species there is a large number; in Brephos, Hydria, Aplodes, Zerene, etc., the number is intermediate, usually one besides *vib*. Alsophila and Brephos, which have additional rudimentary prolegs, have no additional setae on them.

The planta of the Geometridae seems to be developed as a sucker on both ventral and anal prolegs and in several species the hooks in the center of the line are rudimentary to give it room. Such are Alsophila, Zerene, etc.

The ventral proleg varies in position with reference to its segments. In Brephos it is directly below its segment, in Alsophila below the incisure between its segment and the next one behind; in Aplodes, Synchlora, Zerene, Ennomos, etc., it has shifted back almost beneath the following segment.

Examples	**Brephinae**	Brephos nothum
	Hydriomeninae	Alsophila pometaria
		Hydria undulata
	Sterrhinae	Cosymbia lumenaria
	Geometrinae	Aplodes sp.
		Synchlora aerata
	Ennominae	Fidonia truncataria ?
		Zerene catenaria. Fig. 87.
		Lycia cognataria? Figs. 84 to 86.

and several other species unidentified.

Family LACOSOMIDAE.

Prolegs with a complete circle of hooks, alternately of two lengths; body with four setae representing *vii* (the fourth one being probably *vib*) but otherwise without subprimaries; *iv* and *v* approximate below the spiracle, and on a level; all the setae clubbed; head Macro in its type of appearance; higher than wide; front rather high and extending half way to vertex; anal legs with a practically complete circle of hooks; labium with high narrow mentum, and rather small submenta, not meeting.

Example **Lacosoma chiridota,** halfgrown. Figs. 93, 94 and 95

THAUMETOPOEIDAE.

Secondary hair on epicrania, front, adfrontals, mandibles, maxillae and labium, but not on clypeus or labrum. Front small; setae moderate, the punctures trisecting the space between the primaries; as wide as high, adfrontals narrow; labrum with a very shallow cleft, *iii* and *iv* distant, *vi* a very short distance from the margin. Prolegs with hooks all of the same length, in a single band, the anal prolegs with the same number of hooks (18) as the ventrals. Body with tufted hair, the tufts *ii, iii, iv,* and *vi,* as well as *vii* and *viii* of the legless segments, being distinct, the secondary hair is in two transverse bands. Tuft *i* is of short dense hair, making the caterpillar look like a Lymantriid. There are no eversible glands. True legs with very deeply and curiously cleft claws. The family is not American.

These characters suggest very strongly the Lymantriidae, especially Euproctis, without allowing one to deny that they may be due to divergence from a more primitive Notodontan origin. Staudinger and Rebel place it between the two families, which come together in their arrangement. It is usually considered Notodontid.

Example **Thaumetopoea** (of Europe). Figs. 96 and 97.

LYMANTRIIDAE.

With secondary hair on epicrania, adfrontals, maxillæ and labium, and sometimes on front, none on labrum, mandibles, etc.; front rather large, somewhat higher than wide, the punctures close together, the setae, when not obscured by secondaries, very high up and far apart; labrum quite variable; maxillæ and labium much as in the Noctuidae in form. Prolegs with a single band of hooks of a single length, the ventrals and anals equal. Body with tufted, but no secondary hair; wart *i* quite variable and furnishing generic characters, *viii* somewhat diffuse, as if there were a little secondary hair associated with it. Claws of true legs moderately cleft as in most Lepidoptera (similar to Fig. 101). Dorsal glands on 6th and 7th abdominal segments.

1. Labrum more deeply notched, one third its height or more, seta *vi* not on the margin, adfrontals enlarged at the top, with a tuft of secondary setæ; front and upper part of epicrania without secondaries.

2. Labrum cleft about half its height, setæ *i* and *ii* far out of line with each other; body with tufts *i* small, and *ii* moderate, both normal.
Example **Porthetria dispar.**

2. Labrum cleft about a third its height; setae *ii* only moderately out of line with *i*; body with tufts *i* and *ii* of four abdominal segments fused into large square masses.

Example **Hemerocampa leucostigma.** Fig. 98.

1. Labrum less deeply notched, *vi* nearly marginal; adfrontals slender, their secondary setæ inconspicuous; front with secondaries, especially in the lower part; epicrania with a good deal of hair above setae *ii*· warts *i* and *ii* of the first abdominal segments fused to each other, but not fused across the median line.

Example **Euproctis chrysorrhea.** Fig. 99.

NOCTUIDAE.

Prolegs with hooks in a single band, not alternately of two lengths. Usually without secondary or tufted hair, but both are present on the body in Pantheinae and Acronyctini; head with secondary hair on the epicrania, maxillae and labium in the Pantheinae only. Front large, more than a third of the height of the head above the clypeus, the frontal punctures usually close together, never nearer to the setae than to each other; labrum with puncture *ia* considerably nearer to *i* then to *ii*, not very high up; adfrontal puncture rarely more than twice as close to upper as to lower seta; maxillae and labium of about equal width; the submentum at least as wide as the base of the mentum, the labial setae *ai* close together. Setæ of abdomen all well separated, *i* somewhat higher than *ii*, *iv* higher than *v*, *vi* always single and *vii* with three setae except in forms with tufted hair; no caudal horn. In those with tufted hair there are four warts on thorax above the legs, on abdomen three above and two below the spiracle, besides *vii* and *viii*. Never with eversible dorsal glands; anal legs with more hooks than ventrals, one or two pairs of ventral legs often reduced or absent, but never three.

PANTHEINAE: Epicrania, maxillae and labium with considerable secondary hair; adfrontals wide above the top of the front, the puncture about half way between the setae, and above the top of the front. Body with tufts and pencils, with secondary hair also, in Panthea.

Example **Demas coryli.** Figs. 100 and 101.

NOCTUINAE: Head without secondary hair, body occasionally with tufted and secondary hair, or tufted hair only. Adfrontal puncture below the top of the front, and adfrontals rarely much widened at the top (Apatela interrupta); anal legs directed downwards and not lengthened; setae usually short except in hairy forms, distance between upper adfrontal setae less than half height of front; distance between frontal punctures not less than a third that between seta and puncture.

In this group of Noctuinae (or Trifidae) there is a good deal of minor variation between different genera, and even species of the same genus, but my series of forms, though larger than of any other family so poorly represents this enormous group that I shall only characterize the two tribes *Acronyctini* and *Cuculliini* (Cucullianae of Hampson) and mention a few peculiarities of some other genera.*

* I have done nothing whatever with the body setae. Dyar discusses seta iv in Proc. Ent. Soc. Wash. IV, 370 and Pird. in Can. Ent. Vols. 32–34, 39, 40 refers often to variations in the tubercle of the genus Papaipema. See also my "Field Tables," page 140.

Acronyctini: with several-haired warts and often with secondary hair; with fine setiform granulations, with which there may be mixed larger conical ones. Epicrania high, extending over 1 1-3 times the height of the front above its top; adfrontals very wide, the upper setae far apart and high above the top of the front; clypeal setae closer together than the frontal seta and puncture; *i* and *ia* of labrum separated by a distance less than the width of a setigerous puncture; last joint of maxillary pulpus short.

With secondary hair; labrum more deeply notched, *iii* and *iv* of labrum well separated, head dark, front about as wide as high, setae *i* and *ii* of labrum form an angle of about 60 degrees with the horizontal. Adfrontals not especially wide at the top of the front.

Examples **A. (Hyboma) hasta.** Fig. 103.
A. (Triaena) hastulifera. Fig. 102.

Similar; adfrontals with an enlargement at the top of the front, which contains the setae and puncture; labral notch not so deep.

Example **A. (Triaena) occidentalis (interrupta).**
Figs. 1, 12 and 26.

Similar; head pale, labral notch shallower; front narrow; adfrontals unusually high and yet narrow; clypeal setae closer together; setae *i* and *ii* in a line only 30 degrees from the horizontal; *ia* distant from *i*.

Example **A. (Acronycta) leporina.** Fig. 105.

No secondary hair, labrum deeply notched; head black; front narrow; *iii* and *iv* of labrum obliquely placed, separated by only half the vertical distance that separates *i* and *ii* horizontally.

Example **A. (Eulonche) oblinita.** Fig. 104.

No secondary hair; labrum notched only 1-4 its height; front wide.

Example **Simyra (Arsilonche) henrici.** Fig. 106.

In the remaining forms there is no tufted or secondary hair; there are no fine setiform granulations, though there may be coarse ones; the front is larger in proportion to the epicrania and to the adfrontals; the adfrontal setae are closer to the front and to each other; *i* and *ia* of labrum are more widely separated.

Cuculliini Clypeal setae closer together than the distance between frontal seta and puncture, epicrania not reduced, labral setae about evenly spaced.

Adfrontals *i* level with top of front; clypeal setae much closer together than frontal seta and puncture; labral setae *i* and *ii* quite evenly spaced; front as wide as high; adfrontals narrower; setæ of labial palpi long.

Example **Cucullia** sp. (undescribed). Fig. 110.

Adfrontal setae *i* higher, clypeal setae farther apart; labral setae distinctly arranged in pairs; front narrow, adfrontals wider; setae of labial palpi minute.

Example **Scopelosoma** sp.

Adfrontals *i* high, clypeal setae much closer together than frontal seta and puncture; labral setae *i* and *ii* distinctly arranged in pairs; front distinctly higher than wide; setae of palp intermediate.

Example **Calocampa curvimacula.**

Earias chlorana (of Europe) is made the type of a subfamily or placed with Nycteola. Claw very deeply notched; second joint of antenna short, tubercles *ii* of 8th abdominal segment enlarged, and also *ib* of thorax; *ii* of epicrania directly below *i* and close to edge of adfrontals (as in some Micros) front a nearly equilateral triangle, adfrontals quite broad, and rather ill-defined; upper ocellus behind second instead of being above it. Fig. 112.

Rhodophora. Skin coarse and granular (Fig. 138), the coarser granules much more prominent than in Feltia; frontal punctures trisecting the space between the setae; punctures of adfrontals half way between the setae; labrum hardly notched, with setae *i* and *ii* in a straight line. The granular skin occurs also in Heliothis.

Nectua Labrum with setae *iii* and *iv* on a level, prolegs with 40 hooks. (c-nigrum and other unidentified species.)

Feltia. Coarse nodular granulations; first prolegs reduced to half their normal number of hooks and second prolegs slightly reduced; epicrania very low, in the last stage the adfrontals reach the vertex in a way similar to Zygaena. (Three stages). Fig. 108.

Prolegs with only 10 crotchets; epicrania very short; adfrontal punctures half way between the setae. An unidentified species, agreeing with Slingerland's description of Euxoa scandens. Fig. 109.

Hadena (*Trachea*) *turbulenta*. Outer margin of front very sinuous. Fig. 107.

In *Pyrophila pyramidoides*, *Ceramica picta* and two species of *Leucania*, there were no decided characters. The epicrania were a little larger than in the preceding genera.

NYCTEOLINAE: Considered the type of a distinct family by some. Epicrania extending above top of front 1 1-2 times its height; *ep. ii* nearly twice as close together as *i*, yet distant from the adfrontals; labial palpi long and slender; adfrontals broad and ill defined outwardly; ocelli small, the distance between two ocelli being much more than the width of an ocellus. Body-hair long and fine.

Example **Nycteola revayana.** Fig. 111.

CATOCALINAE: Like the Noctuinae, but with the anal legs lengthened, or produced backward; head sometimes held horizontally; never with tufted or secondary hair.

Hind legs not lengthened; prolegs with about 25 hooks; setae *i* and *ii* of labrum at an angle of 30 degrees to the horizontal, *iii* and *iv* obliquely placed and close; epicranial setae *ii* low opposite *adf. i* and distant from *ep. i*.

Example **Ingura** sp.

Anal legs somewhat lengthened, prolegs with about 25 hooks; setae *i* and *ii* of labrum nearly on a level; *iv* higher than *iii*; the two upper ocelli in contact; *ep. i* and *ii* close together near vertex; epicrania extending less than its height above its top.

Example **Drasteria erechtea.**
D. crassiuscula.

Anal legs very long and produced backward, head held horizontally; 45 hooks on prolegs; labrum with setae *i* and *ii* nearly on a level, *iii* and *iv* close, *iii* directly above *iv*; frontal punctures less than twice as close to each other as to the setae; notch of labrum rather shallow; clypeal setae much farther apart than frontal seta and puncture; *ep. i* and *ii* close together on the face. (The conical hump of C. cara lines between them.)

Example **Catocala cara.** Figs. 2 and 3.

Anal legs very long; prolegs with over 50 hooks; labrum with setae *i* and *ii* at an angle of over 45 degrees; *iii* and *iv* distant, frontal punctures decidedly closer together, frontal setae high up; labrum deeply notched; *ep. i* and *ii* close together near vertex.

Example **Panapoda rufimargo.**

HYPENINAE (Deltoides); Setae long and stout, both on head and body; distance between adfrontal setae *i* more than half height of front, and they are also high up; distance between frontal punctures hardly more than 1-4 that between puncture and seta; front small, its setae usually high.

Slender, green, a semilooper with only 14 legs, anal legs produced backward as in Catocala.

Example **Hypena humuli.**

ARCTIIDAE.

Head usually with sparse secondary hair on epicrania, front and maxillae, often also on labium; none on clypeus, labrum, mandibles antennae, etc., or body, rarely on adfrontals (Apantesis). Epicrania rounded, front large, with the punctures about as far apart as the distance between a puncture and a seta; labrum normal, *vi* nearly marginal, puncture usually very high up, and more nearly over *ii* than *i;* adfrontals usually very narrow and irregular, with the puncture close to the upper seta. Maxillae usually somewhat narrower than labium, the base of the mentum about twice as wide as one of the submenta. Body without secondary, but with tufted hair; four warts above legs on thorax, and three above spiracle on abdomen,—all the tubercles below the spiracles developed as separate warts.

LITHOSIINAE: Head without secondary hair, adfrontal puncture close to upper seta; hair not feathered; no pencils or dense dorsal tufts; adfrontals very narrow and wavy-edged; thorax with the two upper warts side by side as on the abdomen. Frontal punctures twice as close together as distance between puncture and seta.

Example **Lithosia complana.**

ARCTIINAE: Head with secondary hair (except Euchaetias, in which the adfrontals are quite wide); hair serrate or feathered on body; often with dense pencils and dense dorsal tufts; warts of thorax all in a vertical line. Punctures of front nearly trisecting the distance between the setae.

Adfrontal punctures about a third way down from upper seta, adfrontals broader; warts *i* and *ii* of abdomen transversely elongate and side by side, bearing dense tufts; with pencils of hair, hair very feathery. Labrum with puncture rather near to setae as in the Noctuidae (When young the puncture is a little nearer to the normal Arctiid position). Frontal punctures decidedly below the level of the setae.

Examples **Halesidota caryae.** Figs. 119 and 120.
H. maculata.
H. tessellaris.

Adfrontal puncture near upper seta; adfrontals, warts and hair suggesting Halesidota; head without secondaries (when very young the warts are as in normal Arctiidae, rather than as in Halesidota). Frontal setae and punctures on a level.

Example **Euchaetias egle.** Figs. 117 and 118.

In the remaining genera the hair is serrate rather than feathery, without dense tufts or pencils; puncture *ia* of the labrum at least as far from *i* as *ii* is; epicrania and maxillae, at least, with secondary hair. Frontal setae and punctures nearly on a level.

Front, labium and maxillae each with several secondaries; an anal tuft of long hair.

Example **Eubaphe nigricans.**

Front with several secondaries: maxillae with about ten secondaries, labium with a single pair; some scattered long hair.

Example **Hyphantria textor.**

Front, adfrontals, and maxillae each with several secondaries, labium without any; adfrontal punctures about a third way down from the setae; no long hair.

Example **Apantesis parthenice** (?) young. Figs. 113 and 116.

Front without secondaries, labium with a single pair, maxillae with about six. Frontal puncture and seta closer together than clypeal setae.

Example **Diacrisia virginica.**

Front with or without secondaries (at most a single pair); maxillae with five secondaries, labium with none; clypeal setae as in the last; no scattered longer hairs.

Example **Isia isabella.** Figs. 114 and 121.

Front without secondaries, stipes with six or seven; clypeal setae nearer together than frontal seta and puncture.

Example **Estigmene acraea.**

Syntomidae.

Prolegs with hooks in a single band, all of the same length. Head with secondary hair on epicrania, front, maxillae and labium, but not on adfrontals, clypeus, labrum, mandibles, etc.; body with tufted hair. Front quite small, the epicrania extending fully twice its height above its top; frontal setae rather close together; adfrontal setae and puncture close together, the puncture almost as near the lower as the upper seta. Labrum with puncture *ia* decidedly nearer *i* than *ii;* labium short and broad, the submenta separated by more than their width at the base. Thorax with only three tufts above the legs, the upper one twice as large as normal and elongate; abdomen with tufts as in the Arctiidae, *i* forming pencils.

Example **Ctenucha virginica.** Fig. 122.

Zygaenina.

Head retracted within the first segment of the body; epicrania with setae reduced; the vertex cleft nearly to the top of the front, or with the cervical skin attached to the epicrania along a similar line; front triangular, about as high as wide, the adfrontals narrow and not extending much above it; frontal punctures about trisecting the distance between the setae, a little farther apart in Zygaenidae; clypeus with setae rather far apart, labrum with *i* no higher than *ii;* mandible with setae close together; maxilla with seta *iv* distinctly arising from the galea, submenta about as wide as base of mentum, or membranous and indistinct; sclerite *b* of labium broad and massive as in the butterflies. Body with *iv* and *v* approximated, or forming the same wart, *i* and *ii* separate or forming the same wart; with tufted or secondary hair,

or with primary hair only, when there is tufted hair there are only two warts on the abdomen above the spiracle. Prolegs with hooks not alternately of the two lengths, or without prolegs.

HETEROGYNIDAE: With primary hair only; prolegs with a single normal band of hooks; head black and heavily chitinized; epicrania with a deep cleft at the vertex; front with the punctures decidedly nearer the corresponding setae, than to each other; labrum with *ii* strong, and no higher than *i;* antenna normal; body with *i* and *ii* well-separated, *iv* and *v* approximated, two setae on a level, in the position of *vi*, but one on the outer side of the proleg, and two on the inner side. It seems clear that the anterior seta on the inner side of the proleg belongs to *vii*, but more doubtful whether the additional seta in the position of *vi* is the other missing one.

Example **Heterogynis paradoxa.**

ZYGAENIDAE: Head as in the preceding, seta *ii* of the labrum decidedly higher than *i*, but fully developed; body with somewhat diffuse tufts of hair, representing, *i*+*ii*, *iii*, *iv*+*v*, *vi*, and two tufts representing *vii; viii* single-haired; hair serrate, but not feathery.

Example **Zygaena trifolii.**

MEGALOPYGIDAE: Head pale, and lightly chitinized, submenta membranous; epicrania with the cleft in the vertex filled up, apparently by the growing together of its edges; their setae rudimentary; labrum with *ii* higher than in Zygaenidae, much smaller than *i*, none of the setae marginal; frontal punctures rather nearer to each other than to the corresponding setae; antenna with first joint about as long as second, second less than twice as long as wide and without any long seta. Body with tufts as in Zygaenidae, but in addition with two isolated setae on a hump, near the tip of the prolegs. The row of hooks on the ventral prolegs is angulate in the middle and the shortest hooks come next to the angle. *viii* is opposite the apex of the angle. Second and seventh abdominal segments with rudimentary prolegs, on which the setae are arranged as on the normal ones, but without any hooks.

Example **Lagoa crispata.** Figs. 123, 124, 125, 126 and 135.

EUCLEIDAE: Mostly like the preceding family. Hair more or less reduced, diffuse, modified into branching spines, or absent;* without prolegs, and without setae on the ventral part of the body; with a row of ventral suckers.

Examples **Cnidocampa flavescens.**
Empretia stimulea.
Euclea delphinii.

NOLIDAE.

With tufted, but no secondary hair. Epicrania, front and clypeus as in the Eucleidae, but with normally developed setae. Labrum with setae normal, *i* lying between setae *ii*, and nearly on

* See Dyar, Journ. N. Y. Ent. Soc., vols. iii to vii for details of structure of the various species.

a level with them; basal joint of antenna nearly as long as second joint, which is short, submenta heavily chitinized and well separated. Body with tufts representing *i*+*ii*, *iii*, *iv*+*v*, *vi*, *vii*, and *viii*, with only two, therefore, above the spiracles, while there are three in the Arctiid types. Prolegs with a single uninterrupted row of hooks, all of the same length; no prolegs on third segment of abdomen.

Example **Nola cucullatella.**

PSYCHIDAE.

Prolegs with hooks all the same length, in a circle broken posteromesally; anal legs similar to the others. Adfrontals massive, their setae well separated, not reaching far above the top of front; *ii* of epicrania close to them; frontal setae far apart, punctures close together and somewhat lower; antennae normal with short second joint; prothoracic spiracle piercing the cervical shield; labrum with *vi* not on the margin. Mera of true legs much enlarged and nearly or quite meeting in the middle line; all segments of the thorax with dorsal plates. Body with setae *i* and *ii* variable, *iv* and *v* close together, *vii* variable, *ii* of ninth abdominal segment distant from each other.

SOLENOBIINAE: True legs very long, and slender; front twice as high as wide; abdomen with *ii* lower than *i*, normal; prolegs with about 15 hooks.

Example **Solenobia pineti.**

PSYCHINAE: True legs short and very stout; front shorter; abdomen with *ii* higher than *i*: prolegs with over 20 hooks.

Front nearly as wide as high; *ii* of abdomen almost directly over *i*;
Example **Thyridopteryx ephemeraeformis.** Figs. 128 and 134.

Front half higher than wide; *ii* of abdomen on the next annulet behind *i*.

Example **Psyche zelleri.** Fig. 127.

COSSIDAE.

Prolegs with hooks in an uninterrupted circle, alternately of three lengths, but with no great difference between the three lengths; the anal legs with hooks in a curved band. No secondary or tufted hair. Epicrania separated by a membranous area at the vertex, a slender prolongation of the adfrontals reaching the vertex; head not retractile. Front higher than wide; the setae far apart and the punctures close together, level with the setae. Adfrontals large, reaching vertex, the setae rather close together, opposite the upper half of the front. Labrum with a shallow notch, *i*, *ii*, *iii*, and *iv* nearly on a level, none of the setae quite on the margin; mandibles extend forward with the cutting edge turned upward for gnawing wood. *Maxillary palpi with second joint very wide and massive, bearing the large cones, which turn inward* as in the Hepialidae; the galea arises from its apex as in other Frenatae, and is quite small. Labium normal with sclerites *b* massive, and *c* slender; palpi rather short; submenta not in contact. Prothoracic spiracle distant from cervical shield; body with setae as in

the Tortricidae; but on a9 the tubercles *ii* are not fused across the middle line.

In the structure of its lower lip this family is very different from the Tortricidae, and may be the most primitive of the Frenatae.

Example **Cossus cossus** (three stages). Figs. 129, 130 and 131

ÆGERIIDAE (SESIIDAE).

No secondary hair; prolegs with hooks in two curved transverse lines, all of the same length, anals rudimentary, with few hooks. Epicrania low, with *ii* rather near the adfrontals, adfrontals practically reaching vertex, their setae close together near the middle, puncture opposite upper seta; front high and lanceolate, setae high, punctures low and not very close together; clypeal setae well separated. Labrum normal; maxillae with large cones part way down the inner side as in Hepialus, but galea arising from second joint of palpus as in Frenatae. Basal joint of antennae massive. Body with *iv* and *v* fused; *vii* is a vertical row of three setae, the middle one the longest. Last spiracles dorsal and higher than *iii;* setae *ii* of A9 separate.

Example **Melittia cucurbitae.** Fig. 132.

MICROLEPIDOPTERA.

As my series of Microlepidoptera is quite short, it does not seem best to discuss the families separately.

Setae *ii* of the epicrania are usually rather close to the adfrontals, as in Argyresthia, but often somewhat more distant. They are never as far away as in the Bombycid series. The front is usually much higher than wide, often twice as high, but in *Endrosis* it is not, and in the *Pyralidæ* there are various intermediate conditions. When the front is high, the adfrontals nearly or quite reach the vertex, but when it is lower the adfrontals may merely border it, as in most Macrolepidoptera. The frontal setae are often far apart, close to the outer edge, as in *Depressaria* and *Homoeosoma*, or they may be closer together, but are never very close, as in the Bombycid series and Zygaenina. In the lower forms the punctures trisect the distance between them, but in the *Tortricidae*, *Pyralidae*, *Depressaria*, *Simaethis*, etc., they are much closer together, and lower, as in the Noctuidae. The adfrontal setae are very close together in *Gracilaria*, but often are not so. The puncture is apt to be about half way between the setae. The labrum is usually not very deeply notched, its setae *i* and *ii* nearly on a level.

The antennae are normal, but often with a seta on the side of the second joint, as in *Yponomeuta* and *Cacoecia*, figured. *Yponomeuta* is very aberrant in the proportions of the joints. The maxillae and labium are rather long, with the sclerites tending

to be well-developed, the maxilla with stipes, palpifer and subgalea sometimes separately chitinized, the submenta not widely separated, or even in contact, (Fig. 137). Setae of mentum rather nearer the base than is typical of the Macrolepidoptera.

There is never secondary hair on the head, and secondary and tufted hair on the body only in the *Pterophoridae*.

Thorax with cervical shield well developed—in the lower forms with additional sclerites ventrally and laterally, which reach their greatest development in *Adela* (Fig. 6). The true legs are absent in *Nepticula*, replaced by patches of enlarged granulations similar to those representing the prolegs.

Abdomen usually with anal plate only, but with two dorsal and two ventral plates on each segment in *Incurvaria*. Setae *i* and *ii* well separated except in the Pterophoridae, *iv* and *v* approximated, except in *Yponomeuta*, where they are distant and *iv* is higher than *v*, they are usually on a single tubercle, and *iv* may be much reduced. *vii* is quite variable, most often in the Tortricidae the setae form an oblique line, while in the Tineina the middle one is anterior. In the *Pterophoridae*, *Thyris*, and *Simaethis* they lie, not on the leg, but on a plate at its base. *Adela* and *Incurvaria* are somewhat different (Figs. 34 and 35). *viii* lies on the anterior side of the leg in *Adela* and *Incurvaria*. On the ninth abdominal segment setae *ii* are both on a single median tubercle in the *Tortricidae*, but in the others they are distinct, and often distant.

The hooks of the prolegs in the Pyralididae and Tortricidae are oftenest in a complete circle, alternately of two or three lengths. They are similar in *Thyris*, *Endrosis* and *Depressaria*. Most Tineidae, as well as *Phalonia* and *Orneodes*, have but a single length. In *Gracilaria* there is half of a second band (Fig. 7). *Adela* has two areas of minute hooks, grading into the granulations, which in Incurvaria are reduced to a single transverse row. *Yponomeuta* has three or four complete circles of hooks. *Nepticula* would appear to have the hooks replaced by a vague area of enlarged conical granulations. In *Panorpa*, there is such an area of enlarged, but setiform granulations, on the posterior side of each of the slender prolegs.*

Tineola resembles Solenobia in its head and ventral prolegs, but its anal prolegs are normal.

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*I am indebted to Dr. E. P. Felt and Prof. J. H. Comstock for the loan of this specimen from the Cornell University collection.

The anal prolegs are wanting in *Adela* and *Incurvaria*, those of the sixth abdominal segment are absent in *Gracilaria* and *Coleophora*, and reduced in *Adela*.

Examples:

Thyris vitrina.
Oxyptilus hieracii.
Botys polygonalis.
Hydrocampa nymphaeata.
Homoesoma nebulella.
Crambus falsellus.
Galleria mellonella.
Orneodes hexadactyla.
Cacœcia cerasivorana. (Figs. 133 and 137).
Carpocapsa pomonella
Several other unidentified Tortricidae.
Phalonia alcella.
Yponomeuta cagnagellus. (Fig. 141).
Simaethis oxyacantha (Figs. 139 and 140.)
Argyresthia goedartella (Fig. 136.)
Sitotroga cerealella.
Depressaria putridella (Fig. 142).
Cosmopteryx scribaiella.
Coleophora.
Endrosis lacteëlla (Fig. 143.)
Gracilaria alchimiella. (Fig. 7.)
Nepticula pomivorella.
Tineola bisselliella.
Incurvaria koerneriella. (Fig. 34.)
Adela degeerella (Figs. 6 and 35.)

Summary.

1. Useful classificatory characters may be found in the structure of the sclerites of the caterpillar head, and the arrangement of their setae.

2. The Sphingidae, Saturniina, Bombycidae, Notodontidae and, perhaps the Lacosomidae, with their related families, show positive points of resemblance, aside from the mere presence of secondary hair in most of them. This is found in the prolegs, subprimary setae, frontal setae and proportions of front and head, and in their habits.

3. The genus *Apatelodes* is a synthetic form with suggestions of Lasiocampidae, Saturniidae, Bombycidae and perhaps Sphingidae. It is not near the Notodontidae. Melalopha is a fairly typical Notodontid.

4. *Lacosoma* is a synthetic form between the Microlepidoptera and Bombyx-Notodontid series, nearer (at least when young) to the Microlepidoptera.

5. Some *Papilios* have the proleg structure of the skippers and Microlepidoptera. It is correlated with a nestbuilding habit.

6. Thyris is a typical Microlepidopter.

7. Cast skins and specimens dried without preparation make fairly satisfactory material for study, thus making it possible to found complete descriptions of larvae on the identical specimens that are bred through and accurately named.

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(Only a few of the most important titles are given, see Edwards, cited above)

Lepidoptera.

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Forbes, Wm. T. M., Field Tables of Lepidoptera, Worcester, 1906.

Contains an analytical key to the better known macrolepidopterous caterpillars of Eastern North America, arranged artificially for convenience in identifying specimens; also their foodplants; and the dates of appearance of a number of the more generally interesting ones.

Rhopalocera.

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Eliot, Ida M. and Soule, C. J., Caterpillars and Their Moths, New York, 1902.

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An artificial key to the species described.

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Gives descriptions of all the stages of the caterpillars studied, with their superficial structural characters. There is little or nothing about their life history proper.

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DYAR, H. G., Annals of the New York Academy of Science, viii, 193.

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STRUCTURE.

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Setae.

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Journal of the New York Entomological Society iii, 68 (Eudeilinea) iii, 17 (Thaumetopoea), iii, 130; iv, 68 (Pericopidae).

Canadian Entomologist xxvii, 325; xxvii, 159 (Apatelodes); xxviii, 2; xxviii, 103.

Entomological News vi, 38 to 40 and 100. (Pterophoridae).

Psyche vii, 259 (Clisiocampa).

EXPLANATION OF THE FIGURES.

PLATE X.

FIG. 1. Front view of head of caterpillar (Apatela), with setae numbered.
adf., adfrontal sclerite; *adf. i*, *adf. ii*, its setae.
adf. o., adfrontal puncture.
fr. i, frontal setae. *fr. o.*, frontal puncture.
cl. i., and *cl. ii.*, clypeal setae.
lbr., labrum.
ant., antenna.
md., mandible. *md. i.* and *md. ii.* its setae.
i to *xi*, setae of epicrania.

FIG. 2. Under lip of caterpillar (Catocala).
S. m., Submentum.
Ment., Mentum.
m. i., mental seta.
c., Cardo.
St., Stipes.
i and *ii*, Setae of stipes.
iii, Seta of first joint of maxillary palpus.
mx. p., Free part of maxillary palpus.
(See also Figures 3 and 26.)

FIG. 3. Tip of labium of Catocala.
Seta of sclerite *a*.
a. i. b., Sclerite *b*, perhaps the palpifer.
b. o., Punctures of sclerite *b*.
c. o., Puncture of sclerite *c*.
seg. 1, *Lb. p*, *seg.* 3, The three joints of the labial palpus.
Sp. Spinneret.

FIG. 4. Seta plan of a typical (Noctuid) caterpillar; metathorax. In these diagrams a single segment is represented as if cut on the mid-dorsal and mid-ventral lines, and laid flat. The anterior edge is to the left, and the mid-dorsal line at the upper edge.

FIG. 5. Seta plan of a middle abdominal segment of the same type.

FIG. 6. Proleg of Adela, with the setae numbered, ventral view.

FIG. 7. Proleg of Gracilaria, lateroventral view.

FIG. 8. Proleg of Noctuid caterpillar, lateral view; seta viii is shown in dotted lines as if seen by transparency, and the roots of the hooks are represented in the same way.

FIG. 9. Arrangement of hooks on the proleg of a Sphingid or Bombycid caterpillar.

PLATE XI.

FIG. 10. Proleg of Papilio polyxenes, somewhat flattened; seen from the median side.

FIG. 11. Proleg of Jasoniades glaucus, split down the side to the planta and flattened out.

FIG. 12. Labrum of Acronycta, showing typical arrangement of setae, and one of the punctures.

FIGS. 13 to 24. Labra of butterflies: drawn to the same scale.

13. Anosia plexippus.
14. Argynnis cybele.
15. Euphydryas phaeton.
16. Polygonia interrogationis
17. Euvanessa antiopa.
18. Basilarchia disippus.
19. Cercyonis alope.
20. Pieris rapæ.
21. Papilio polyxenes.
22. Jasoniades glaucus.
23. Epargyreus tityrus.
24. Pholisora catullus.

FIG. 25. Labium of an Elater beetle larva (compare with Figs. 2 and 32).

PLATE XII.

FIG. 26. Tip of left maxilla of a Noctuid caterpillar, caudal aspect.
iv and *v*, setae of second segment of palpus.
palp. 1, First free segment of palpus.
2, Second free segment of palpus.
base, Basal segment of galea.
mx. l., Maxillary lobes.
l. c., Inner large cone, the outer one is behind the outer maxillary lobe.
st. c., Step cone.
s. c., Small cone. The inner one is in front of the inner maxillary lobe.
FIG. 27. Tip of maxilla of Hepialus (Jugatae), caudal aspect.
FIG. 28. A typical mandible (Phlegethontius quinquemaculatus, side view of right mandible).
FIG. 29. A typical antenna (Diacrisia virginica), side view of right antenna. (The long seta is posterior).
FIG. 30. Arrangement of eyes of right side in the Jugatae (Hepialus hectus).
FIG. 31. Arrangement of eyes of right side in the Frenatæ (Demas coryli).
FIG. 32. Maxilla and labium of a sawfly. The right maxilla is not shown. The part of the maxilla covered by the labium is indicated in dotted lines.
FIG. 33. Seta plan of middle abdominal segment of Hepialus hectus; compare Figs. 4 and 5.
FIG. 34. Same of Incurvaria, showing also the dorsal and ventral sclerites.
FIG. 35. Ventral view of pro- and mesothorax of Adela.
St., Sternum.
Cx., Coxa.
F., Femur.
T., Tibia.
tr., Trochanter.

PLATE XIII.

FIG. 36. Labium and maxillae of Basilarchia disippus. The drawings of lower lips were made with the camera lucida, and they are drawn as they appeared in the prepared specimens. They are usually somewhat retracted, on one or both sides. In life the labium is usually folded so that the spinneret lies at right angles to the rest, and the base of the spinneret and the setae *ai* at least, are concealed.
FIG. 37. Labrum of Libythea celtis, on the same scale as the other butterfly labra.
FIG. 38. Labrum of Thella ilicis.

SPHINGIDAE.

FIG. 39. 40 and 41. Head, labrum and lower lip of Dolba hylaeus (?).
FIG. 42. Sketch of head of Paonias myops, to show the form.
FIG. 43 and 44. Front and labrum more enlarged.
FIG. 45. Head of Ceratomia amyntor.
FIG. 46. Head of Deilephila gallii.
FIG. 27. Head of Pseudosphinx tetrio.

PLATE XIV.

FIG. 48 and 53. Head and labrum of Amphion nessus.
FIG. 49. Labrum of Ceratomia amyntor.
FIG. 50. Labrum of Pseudosphinx tetrio.
FIG. 51. Labrum of Phlegethontius carolina.
FIG. 52. Labrum of Deilephila gallii.
FIG. 54, 55 and 56. Head labrum and lower lip of Apatelodes torrefacta.

ENDROMIDAE.

FIG. 57. Labrum of Endromis versicolor.

BOMBYCIDAE.

FIG. 58. Labrum of Bombyx mori.

LASIOCAMPIDAE.

FIG. 59 and 60. Antenna, and front and labrum of Malacosoma disstria.

CERATOCAMPIDAE.

FIG. 61. Head of Basilona imperialis.
FIG. 62. Labrum of Anisota senatoria.
FIG. 63. Labrum of Citheronia regalis.

PLATE XV.

FIG. 64. Head of Anisota senatoria.
FIG. 65. Labrum of Basilona imperalis.

SATURNIIDAE.

FIG. 66. Head of Hyperchiria io.
FIG. 67. Maxillae and labrum of a half grown larva, supposed to be H. io.
FIG. 68. Maxillae and labium of adult larve of H. io.
FIG. 69. Labrum of Telea polyphemus. That of normal Tropaea luna is similar, but lacks the secondary hair.
FIG. 70. Maxillae and labium of T. polyphemus.
FIG. 71. Labrum of Tropaea luna. An aberration, apparently due to injury and imperfect regeneration. The form is changed, and setae *iii*, *iv* and *vi* are lost on the right side.
FIG. 72. Head of Tropaea luna. That of polyphemus is similar.

NOTODONTIDAE.

FIG. 73. Front and labrum of Datana integerrima.
FIG. 74. Front and labrum of Schizura concinna. That of S. badia is quite similar.
FIG. 75. Front and labrum of Cerura, penultimate stage.

PLATE XVI.

FIG. 76. Head of Melalopha.
FIG. 77. Ventral proleg of Cerura, extended.
FIG. 78. Anal leg of Datana ministra, penultimate stage, seen from the ventro-lateral point of view.
FIG. 79. Lateral view of stemapod, or anal proleg of Cerura, with the tip of the body.
FIG. 80. Nearly lateral view of anal proleg of Heterocampa guttivitta; about half of the row of crotchets is shown.
FIG. 81. Ventral proleg of the same, half retracted; extended it would resemble Figure 77 quite closely.
FIG. 82. Labrum of H. guttivitta. Nadata is quite similar.
FIG. 83. Labrum of Melalopha.

GEOMETRIDAE.

FIG. 84. Head of Lycia cognataria (?).
FIG. 85. Lateral view of sixth abdominal segment of the same, showing normal Ennomid position of the proleg, and seta *vib*.
FIG. 86. Labrum of the same.
FIG. 87. Ventral view of proleg of Zerene catenaria, opened on the outer side and flattened, to show the sucker, interrupting the row of hooks.

THYATIRIDAE.

FIG. 88. Heax of Cymatophora (Bombycia) or. Sketch to show form of epicrania.

DREPANIDAE.

FIG. 89. Front view of head of Drepana arcuata.
FIG. 90. Seta plan of the same. The leg is indicated very diagrammatically.
FIG. 91. Labrum of the same.
FIG. 92. Lateral view of ventral proleg, showing the three true setae *vii*, the outer row of rudimentary hooks, and the two ends of the developed inner row.

PLATE XVII.

LACOSOMIDAE.

FIG. 93. Ventral view of proleg of half-grown Lacosoma chiridota.
FIG. 94 and 95. Lower lip and head of L. chiridota.

THAUMETOPOEIDAE.

FIG. 96 and 97. Labrum and claw of true leg of Thaumetopoea (Cnethocampa) pityocampa.

LYMANTRIIDAE.

FIG. 98. Front and labrum of Hemerocampa leucostigma.
FIG. 99. Labrum of Euproctis chrysorrhea.

NOCTUIDAE.

FIG. 100. Head of Demas coryli.
FIG. 101. Tip of true leg of D. coryli. The moderately notched claw, and the three spatulate setae are typical, but not universal in the Macrolepidoptera.
FIG. 102 to 105. Labra of various species of Acronycta, to show variation within the genus.
FIG. 106. Labrum of Arsilonche henrici.
FIG. 107. Head of Hadena (Trachea) turbulenta.
FIG. 108. Head of Feltia sp.
FIG. 109. Part of head of Euxoa sp.
FIG. 110. Front of Cucullia sp.
FIG. 111. The ocelli of Nycteola revayana. (Right side).
FIG. 112. The ocelli of Earias chlorana.

PLATE XVIII.

ARCTIIDAE.

FIG. 113. Head of Apantesis parthenice (?); the setae are somewhat shorter than in life, but not so much so as in most of the figures of heads in this paper.
FIG. 114. Head of Isia isabella.
FIG. 115. Mandible of the same, seen from the inner aspect.
FIG. 116. Mandible of Apantesis. (Of the opposite side).
FIG. 117. Front and labrum of Euchaetias egle.
FIG. 118. Lower lip of E. egle.
FIG. 119 and 120. Front and labrum more enlarged of Halesidota caryae.
FIG. 121. Labrum of Isia isabella.

SYNTOMIDAE.

FIG. 122. Labrum of Ctenucha virginica.

MEGALOPYGIDAE.

FIG. 123. Lower lip of Lagoa crispata.
FIG. 124. Antenna of L. crispata (seen from the ventral side).

PLATE XIX.

FIG. 125. Labrum of Lagoa crispata.
FIG. 126. Half of the same, more enlarged.

MICROLEPIDOPTERA.

FIG. 127. Front view of head of Psyche zelleri.
FIG. 128. Ventral view of proleg of Thyridopteryx ephemeraeformis.
FIG. 129. Sketch of lower lip of Cossus cossus, showing the general arrangement and proportions of parts.

FIG. 130. Tips of maxillae and labium of Cossus cossus; copied from Lyonnet. Twice the size of the original engraving. Only a small part of Lyonnet's figure is shown.
g. Subgalea.
d. f. Maxillae.
e. Mentum.
H. Maxillary palpus. The dotted line runs to the enlarged second joint characteristic of Cossus.
K. Labial palpi.
I. Sclerite *c*. at the base of the spinneret.
T. Large cones.

FIG. 131. Skin of Cossus cossus. Opened from the dorsal side, and with the larger muscles removed to show the retractor muscles of the proleg (2). The proleg itself is represented by an indistinct ring at the right end of the muscle. The midventral line runs just to the left of the muscle marked P. This is also a copy of a small part of one of Lyonnet's figures, enlarged about twice.

FIG. 132. Antenna of Melittia cucurbitae. (Sesiidae).

FIG. 133. Antenna of Cacoecia cerasivorana (Tortricidae).

PLATE XX.

VARIOUS FAMILIES.

FIG. 133. Partly lateral view of spinneret and neighboring parts of Thyridopteryx ephemeraeformis (Psychidae) to show an unusual amount of development of the sclerites.

FIG. 135. Ventral view of proleg of Lagoa crispata (Megalopygidae).

FIG. 136. Head of Argyresthia. (Tineina).

FIG. 137. Maxillae and labium of Cacoecia cerasivorana. (Tortricidae).

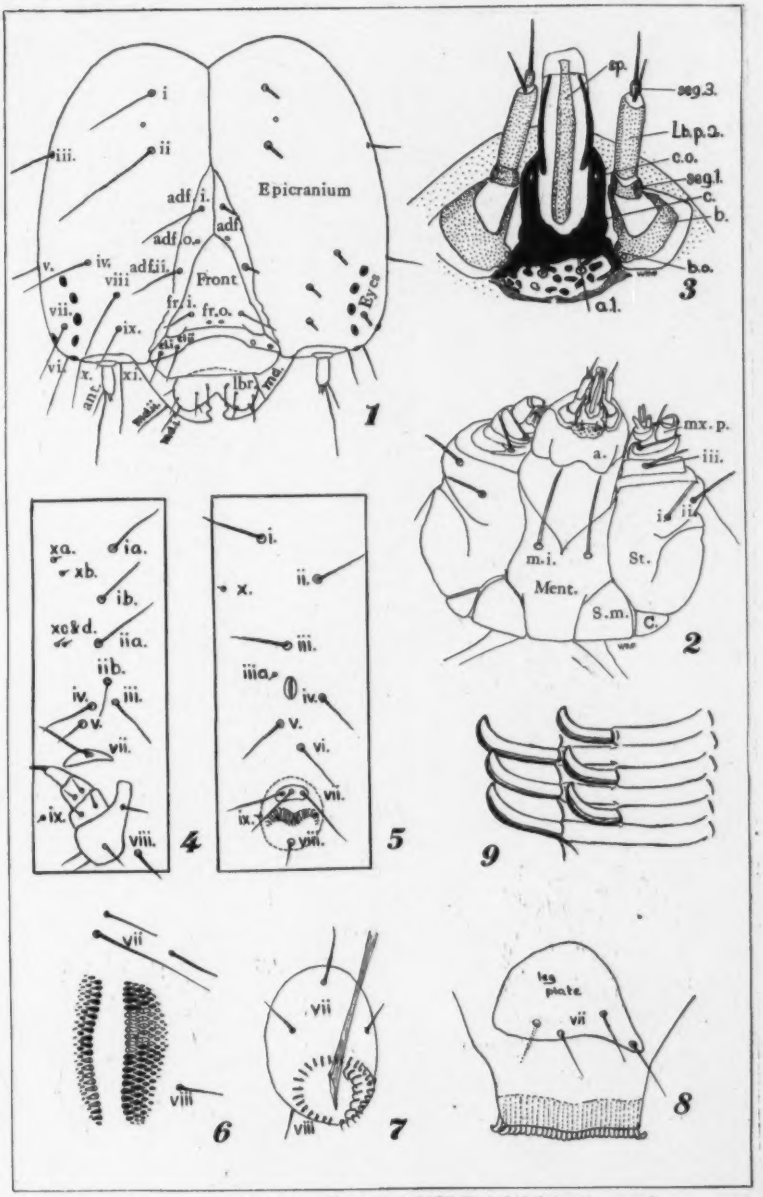
FIG. 138. Portion of skin of Rhodophora florida (Noctuidae) to show the type of granulation.

FIG. 139 and 140. Head and antenna more enlarged of Simaethis oxyacantha (Tineina).

FIG. 141. Antenna of Yponomeuta cagnagellus. (Tineina).

FIG. 142. Head of Depressaria putridella. (Tineina).

FIG. 143. Head of Endrosis lacteella. (Tineina).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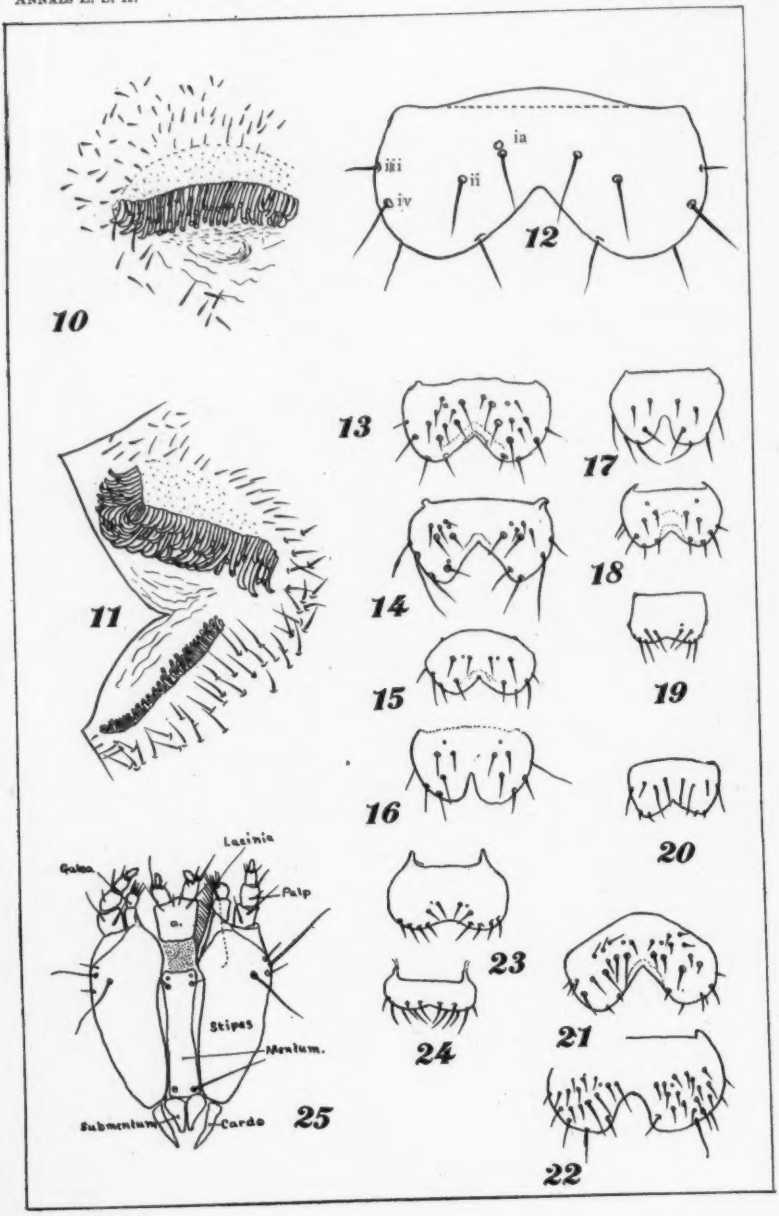
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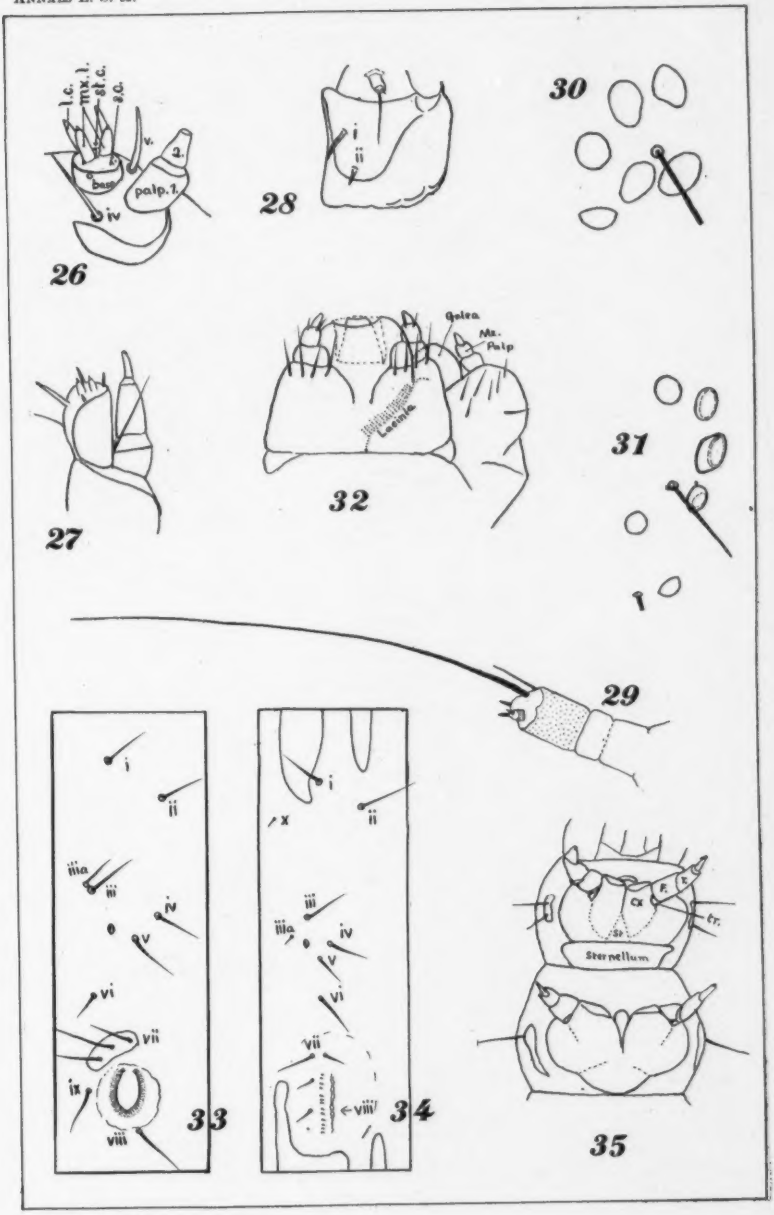
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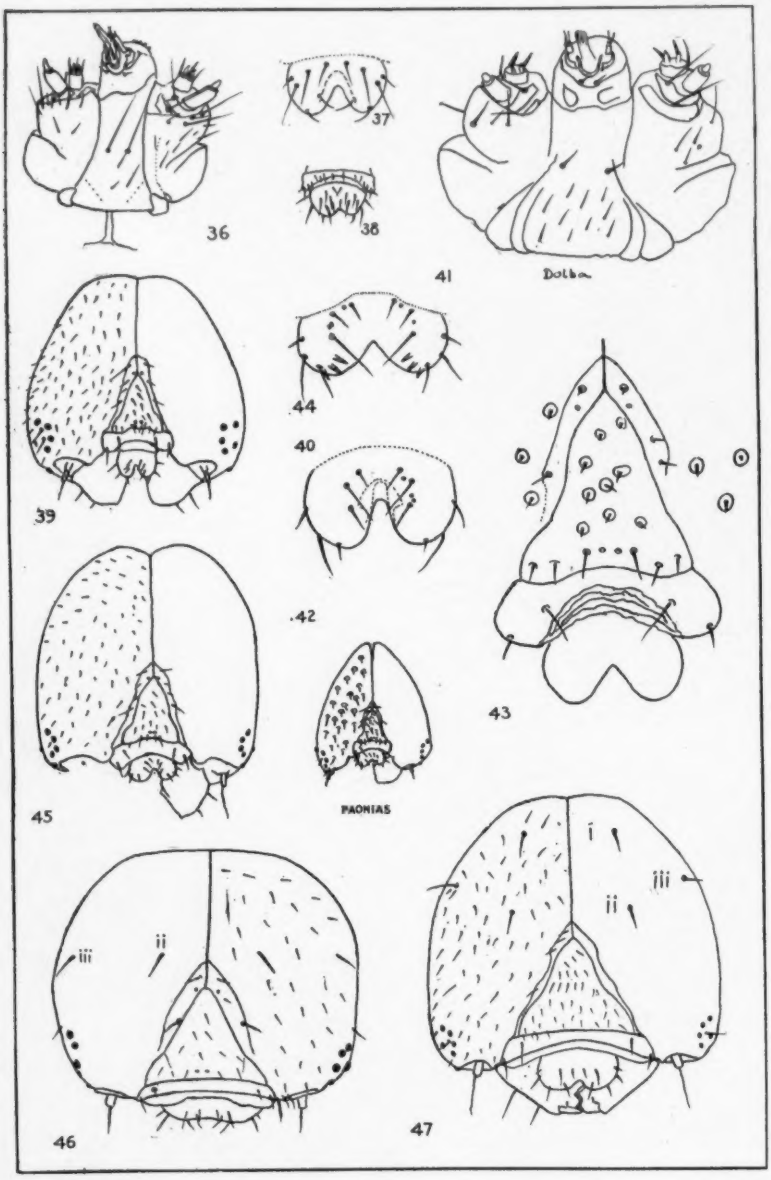

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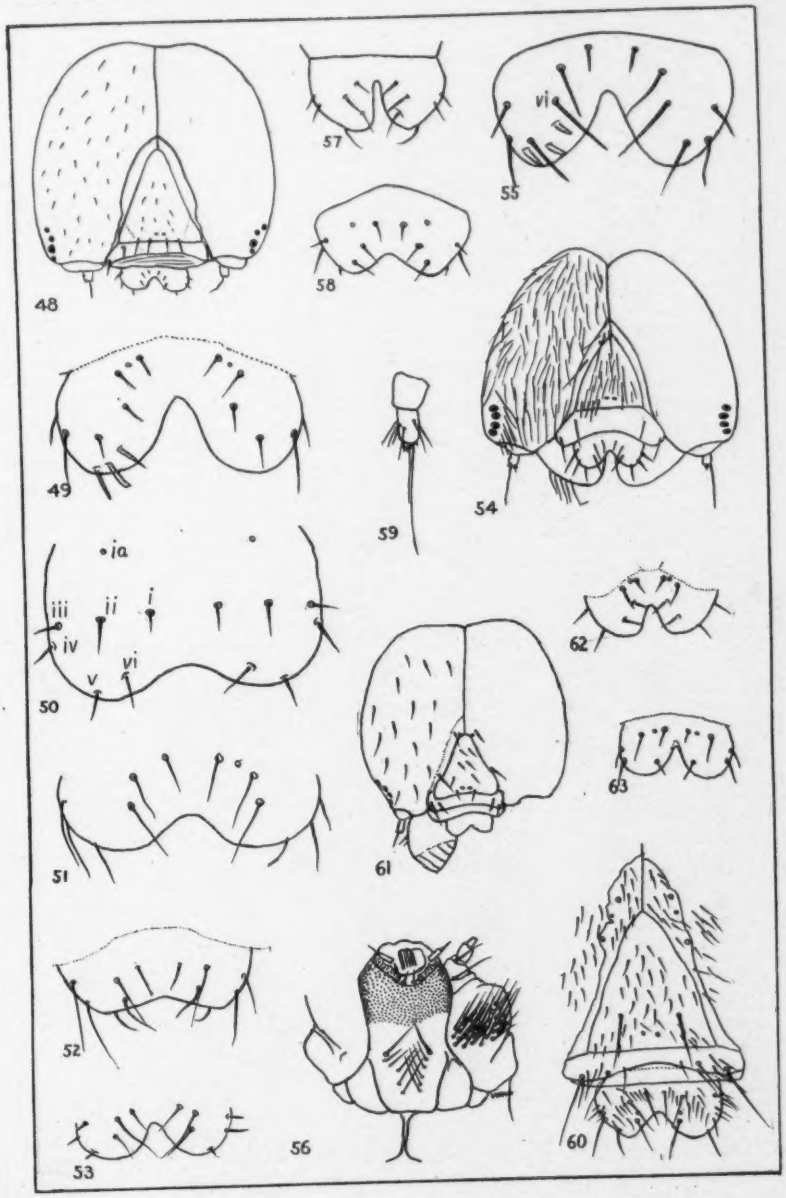

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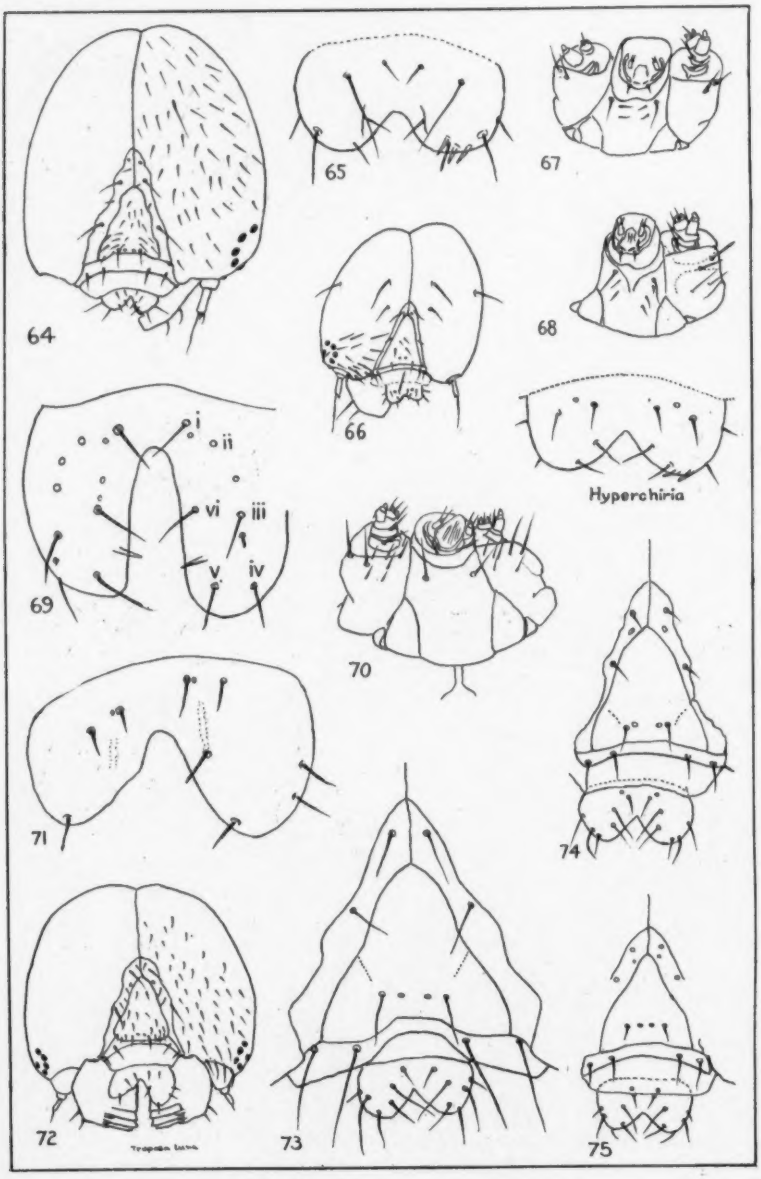

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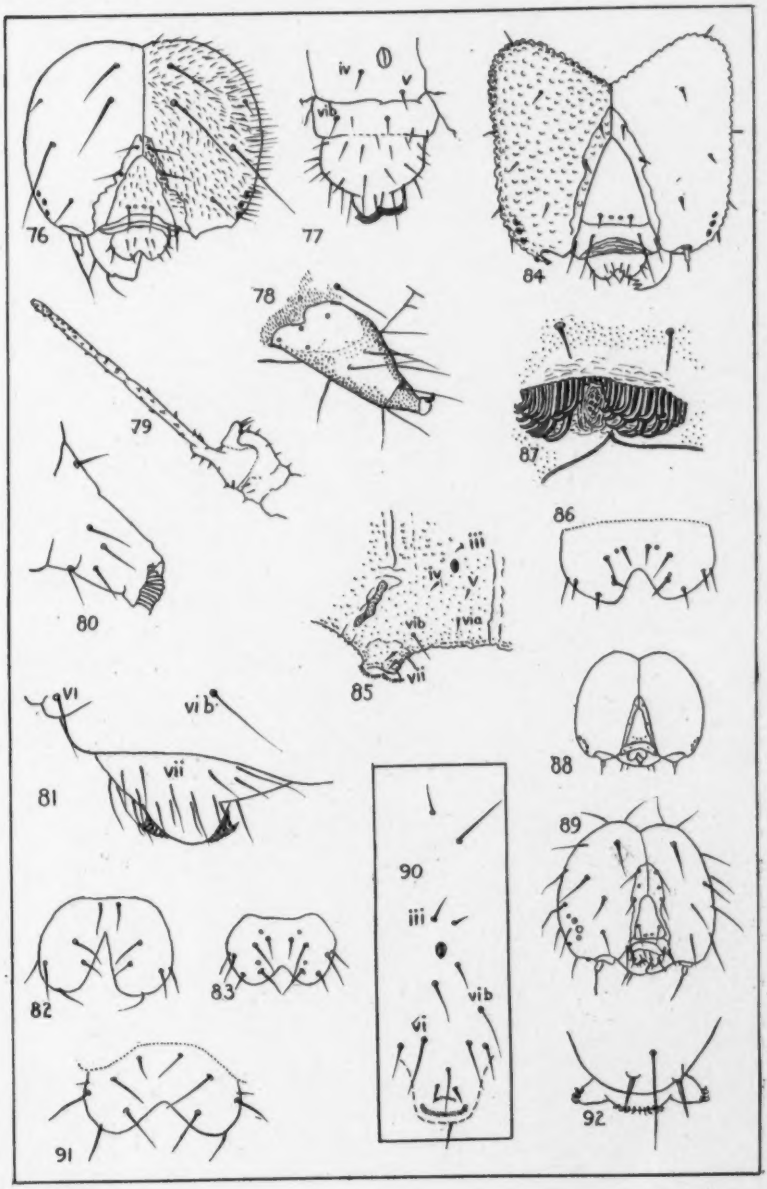
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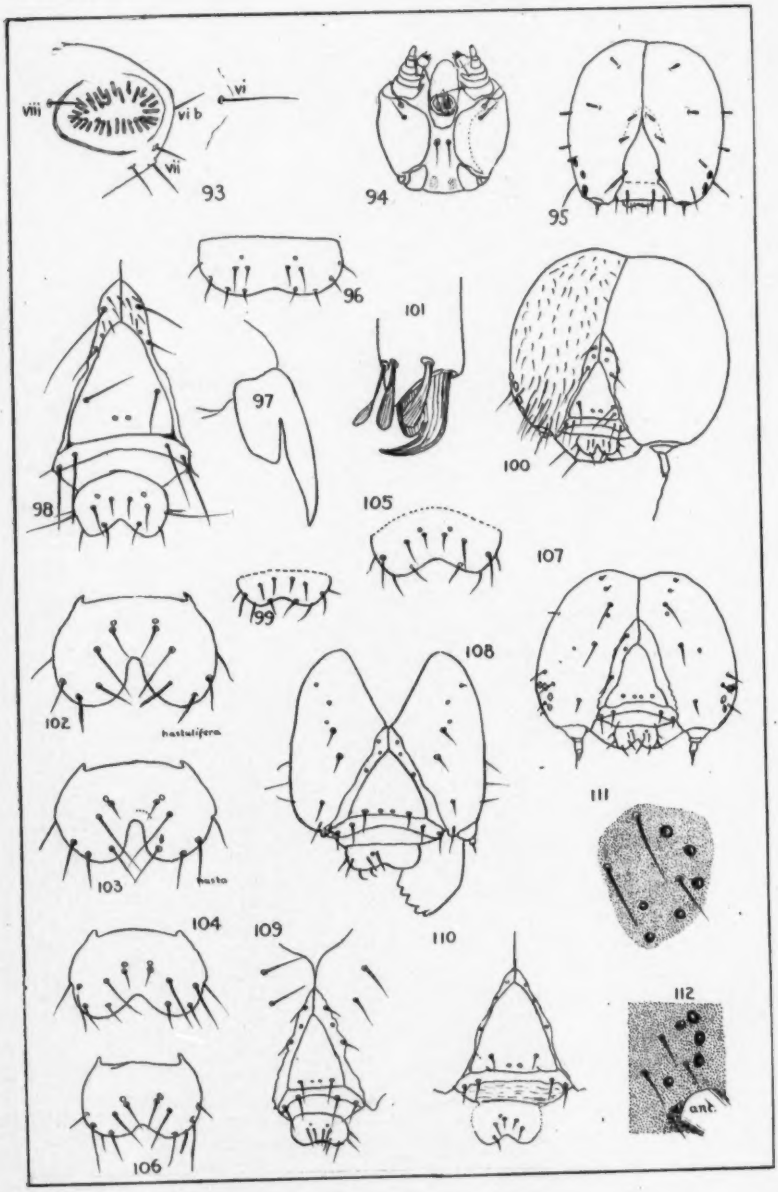
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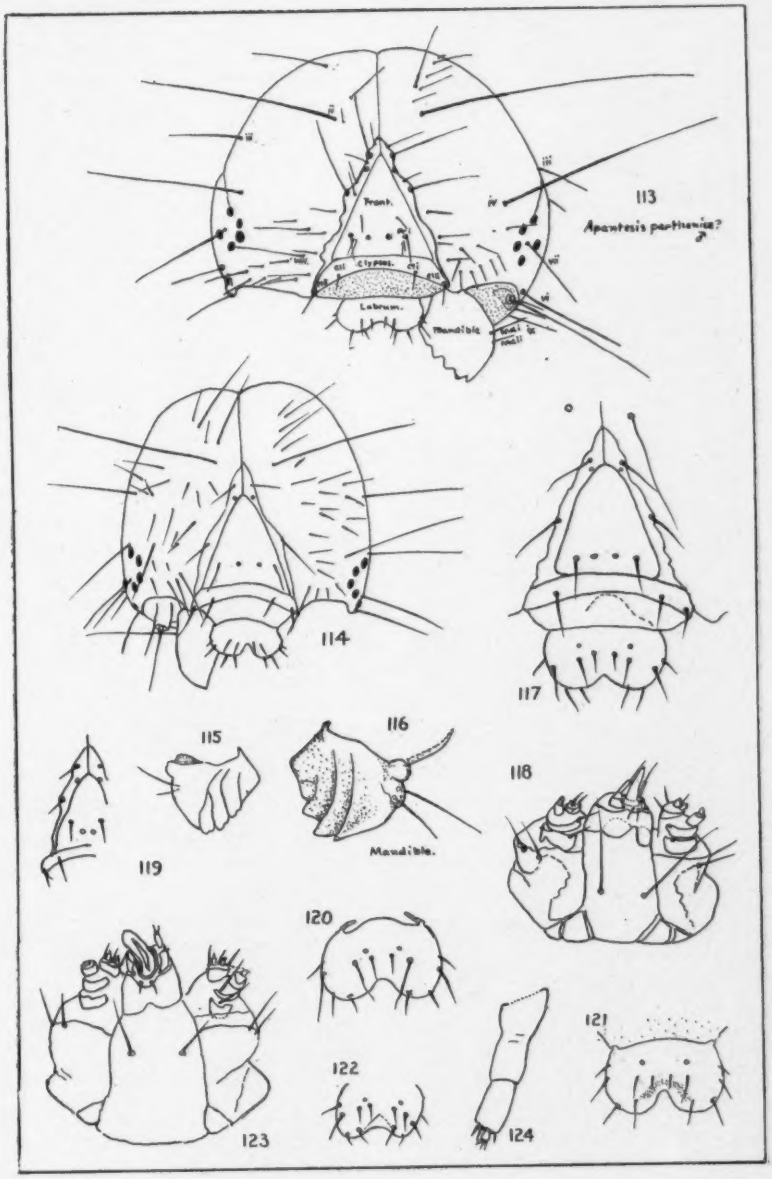
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Apantesis parthenice? ♂
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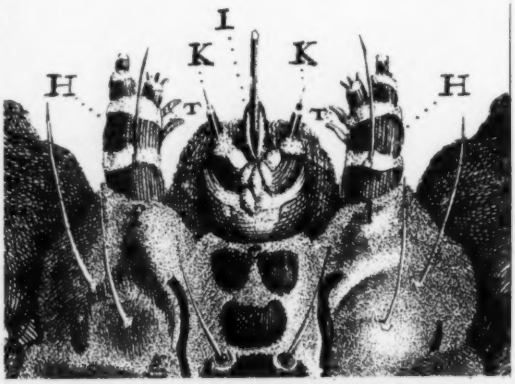

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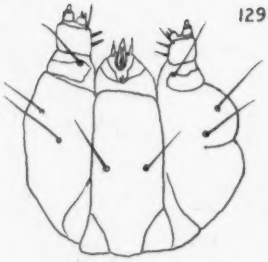

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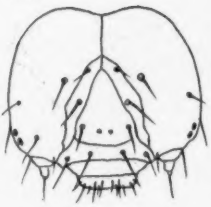

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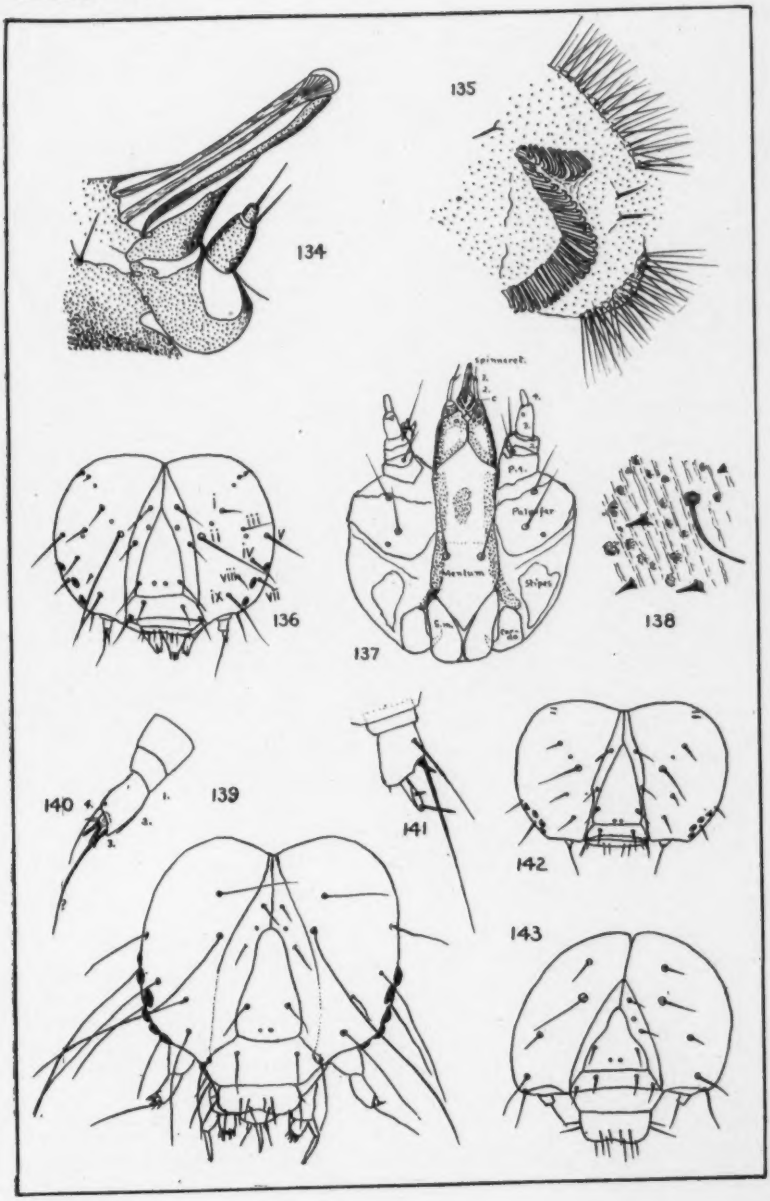
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Pal.
Palpifer
Mentum
Stipes

W. T. M. Forbes.

THE LIFE CYCLE OF HORMAPHIS HAMAMELIDIS.

By T. H. Morgan and A. F. Shull.

Pergande* has described the life cycle of this species as consisting of seven generations, the first two and the sexual generations living on the witch hazel, and the other four on the black birch (Betula nigra), the latter four generations consisting of three aleurodiforms and one winged migrant.

Failure on our part to discover the aleurodiform generations in localities where the witch hazel was abundant, and the discovery that the winged migrants continued to emerge from the galls from the end of July until October, thus leaving no time for the intercalation of the four birch generations, led us to examine the life cycle of this species in the vicinity of New York.

Leaves of the witch hazel bearing galls of Hormaphis were enclosed in bags of paraffin paper about the first of August, when the migrants had begun to leave the gall. The bags were opened at intervals of about a week, and the under surface of the leaves examined. Nothing was found until about the first week in September, when the sexual forms were discovered on the leaves which had been in the bags. At the same time the sexual forms were also found on the leaves outside. The results show at least that the birch is not a necessary link in the life cycle of this species; and since no aleurodiform individuals were seen at any time on the witch hazel, their necessary occurrence in the life history seems, in this locality at least, to be excluded.

The final and conclusive evidence was obtained from a microscopic examination of the migrants within the witch hazel galls, and of the young stages, pupal and prepupal. Serial sections show that all these forms contain embryos that are males or females. The determination of the male embryos can be made owing to the fact that the testes early develop, and in the embryos in the winged stages of the migrant the characteristic spermatcoyte divisions can be found. In all of these, as in other aphids, a lagging chromosome is present, and two classes of sperm, functional and rudimentary, result. The determination of the sexual female can be made owing to the presence of a sypegesis stage in the eggs in the ovary.

* Pergande, Theo. "The Life History of Two Species of Plant-lice Inhabiting Both the Witch-Hazel and Birch." U. S. Dept. of Agr., Div. of Entomology, Technical Series No. 9, 1901.

At Cold Spring Harbor, where these observations were made, three birches are present: Betula lenta is common, B. populifolia is uncommon, and B. lutea is rare. B. nigra is said to occur, but was not found. Winged migrants were placed on the leaves of the first three of these species in the evening; those on leaves of trees outside had left by 9 A. M. the next day; some of those on branches in the laboratory remained during the day, and were seen as late as 4 P. M., but had left by 8 A. M. on the following morning. They appear not to have deposited any young, since none appeared on the leaves during the following two weeks.

A branch of witch hazel with leaves bearing galls, and one of a birch (B. lenta), growing near together, were enclosed in the same bag. After about three weeks the bag was opened, when sexual individuals were found on the witch hazel leaves, but none on the birch.

The observations show that in the vicinity of New York, Hormaphis has a much simpler life history than that ascribed to this species by Pergande for the vicinity of Washington. It would seem to follow, either that further south there is a longer life cycle including an alternate host, or that Pergande has intercalated in the life cycle of this species several generations of some other (aleurodiform) species. Fortunately the question can be very simply decided by making a few serial sections of the winged migrants in the galls found in the District of Columbia.

Pergande's statement is so definite and detailed that it scarcely seems possible that he could be mistaken in regard to the life history of the Washington form. For example, he states on page 17, regarding the third generation: "Toward the middle or end of June the insects cast their third or final skin and assume a most remarkable mimicry; in fact, mimic now so closely certain Aleurodids that for some time I was completely deceived as to their true nature, which only after close examination of numerous specimens, in connection with its earlier stages, was disclosed. When seen on the leaves they are to all appearances true Aleurodids, both in shape and size, resembling to some extent the scale-like form of Aleurodes corni or related species." The fourth and fifth generations are also aleurodiform. "With the appearance of the sixth generation a new cycle of forms begins to make its appearance, in which the aspect of the insects has changed completely, so much so that the casual observer would fail to trace a connection between them and the Aleurodiform generations.

Continued observations, both in the woods and on small potted birches to which the insects were transferred, removed, however, all doubt as to the close relationship of these aberrant forms. This generation develops in time into the return migratory generation."

The return of the migrants to the witch hazel is described by Pergande as follows (p. 21): "Having cast their fourth or final skin, they acquire wings and, after feeding for some time to complete maturity, forsake the birch and migrate back to witch hazel to deliver themselves of the ultimate or sexual generation. Each migrant, according to size, contains from seven to fifteen or perhaps more larvae. Migration continues for about a month and a half, according to conditions of the season and other natural causes, and commences usually toward the end of August and terminates during the early part of October. In general appearance they are essentially the same as those of the spring migrant from the witch hazel, though they are uniformly smaller * * * ." From these statements it appears that Pergande has observed not only all the intermediate stages between the young of the spring migrants from the witch hazel and the aleurodiform generations on the birch, but also the development of the return migrant from the aleurodiform individuals on small potted birches in confinement.

AN APPARATUS FOR THE DETERMINATION OF OPTIMUMS OF TEMPERATURE AND MOISTURE.

By THOMAS J. HEADLEE,
Manhattan, Kansas.

Pioneer work in economic entomology consisted in the determination of the insect's life history and habits without more than casual regard to the environment in which it lived. From time to time, however, various workers have called attention to the fatal effects of the extremes of temperature and moisture, and a few persons have pursued systematic inquiry into the relations existing between temperature and insect life. Others have used various arthropods in determining the response of protoplasm to various stimuli. The last two types of investigation have proceeded far enough to show that insects in common with other organisms have minimum, optimum and maximum relations to each important stimulus to which they are subjected. More than enough work has been done to show that the life economy of the insect depends to a very large extent directly and indirectly upon the physical, chemical, and animate environment in which it lives, and that no fundamental understanding of its life economy can be reached until the effect of its environment is understood.

While the study necessary to the accumulation of sufficient data to arrive at such an understanding is one requiring much time and expense, certain insects are of such transcendent economic importance that the expenditure of enough time and money to make the most exhaustive study is entirely justifiable. Such insects have as a rule already received pioneer study and a few, owing to their especially marked response to environmental factors, have received more fundamental attention. The writer was first led to see the necessity for making a more fundamental study of highly injurious species by the observation that for certain of the insects most injurious to staple crop production—insects that exact a yearly toll of millions from the state in which he is now located—only inadequate measures of control have been devised, although they have been subjects of study for many years.

In making a study of the relation of environmental factors to the life economy of insects, either the investigator must deal with a sufficiently large number of individuals and instances to

FIG. 1

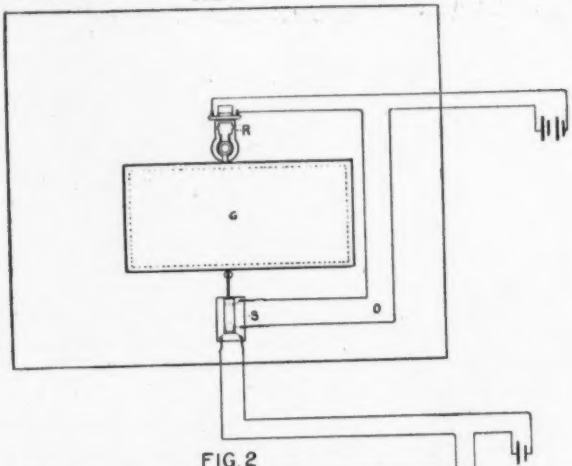
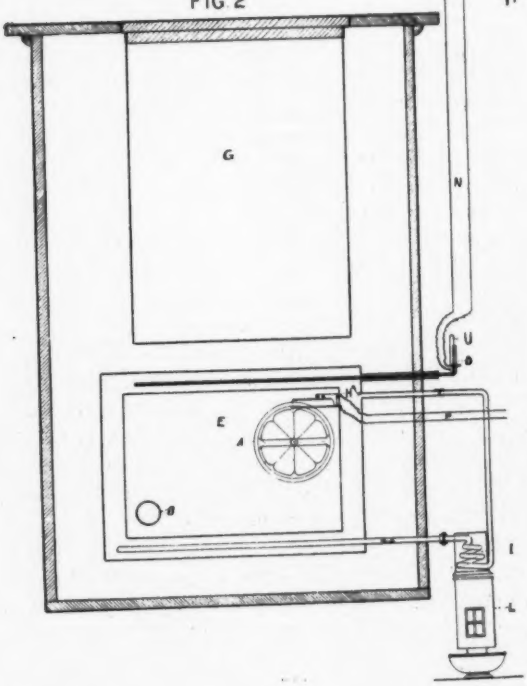


FIG 2



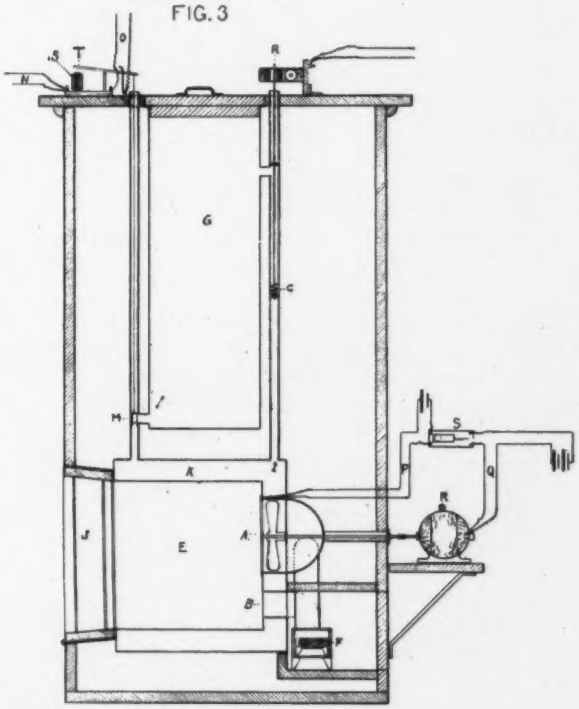
T. J. Headlee.

DIAGRAMATIC VIEW OF CONSTANT TEMPERATURE AND MOISTURE INCUBATOR.

FIG. 1 = TOP VIEW
FIG. 2 = FRONT VIEW
FIG. 3 = SIDE VIEW

A = EXHAUST FAN AND PASSAGE WAY TO LEAD BOX
B = PASSAGE FROM LEAD BOX
C = SPIRAL LIFT
D = THERMOSTAT
E = EXPERIMENT CHAMBER
F = LEAD BOX CONTAINING CALCIUM CHLORIDE
G = ICE CHAMBER
H = HYGROSTAT
I = HEATING COIL
J = GLASS FRONT OF CHAMBER
K = WATER JACKET
L = KEROSENE HEATER
M = VALVE
N = TEMPERATURE-MAGNETIC CIRCUIT
O = " -MOTOR "
P = MOISTURE-MAGNETIC "
Q = " -MOTOR "
R = MOTORS
S = ELECTRO-MAGNETS
T = LEVER U = ELECTRODE

FIG. 3



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reduce the error of the average to a negligible quantity, or he must deal with smaller numbers under conditions in which the important variables are reduced to constants.

In planning a study of the life economy of certain insects most injurious to staple crop production, the writer has adopted the plan of using the smaller number of individuals and of reducing the number of variables to a minimum. Of course it has been easy to eliminate natural enemies and to prevent large variation in the quantity and quality of food supply, but of the physical factors he has thus far been able to reduce only temperature and moisture to constants. This has been accomplished through the construction of an incubator, in which, within limits, desired degrees of each can be maintained.

Construction of the Apparatus. Plates XXI–XXII.

Temperature Phase.

Essentially the incubator consists of a water-jacketed chamber E (figs. 2 and 3) with special provision for heating and cooling the water within the jacket, the whole being surrounded by a box filled with non-conducting packing. The packing used in this instance consisted of wood shavings. The 12″ x 12″ x 18″ chamber is jacketed on three sides only, the fourth being closed by a double glass door for the purpose of admitting light. The water is cooled by the inflow of ice water from tank G (Fig. 3). This exchange is automatically controlled by means of mercurial thermostat D (fig. 2), which projects far into the jacket.

The platinum-tipped electrode U (fig. 2) has been so adjusted that when the temperature of the water within the jacket rises higher than is necessary to bring the air in chamber E (fig. 3) to the desired point, the rising mercury column in D (fig. 2) makes contact with it and completes magnetic circuit N (figs. 2 and 3), magnetizing electromagnet S (fig. 3), pulling lever T (fig. 3) down upon it, thus pulling valve M out of its seat and allowing ice water to flow by gravity into the jacket. The pulling of the lever down on the electromagnet S (fig. 3) completes motor circuit O (figs. 1 and 3), and sets spiral lift C (fig. 3) in motion. This interchange impelled by gravity is thus hastened by pumping. This interchange continues until enough cold water has been introduced into the jacket to cause the mercury column in D (fig. 2) to withdraw from the electrode U (fig. 2). So soon as this happens valve M (fig. 3) falls back into its seat and spiral lift C (fig. 3) stops.

The water within the jacket is heated in coil I (fig. 2) by means of kerosene burner L (fig. 2). The method of heating could be greatly improved where constant electric current is available by the installation of electric heaters under chamber E (fig. 3) and the controlling of the amount of current delivered by some form of thermostat. This portion of the incubator was devised and constructed by the "International Instrument Company," and later so modified by the writer as to fit it for his use.

Moisture Phase.

While certain companies would undertake the construction of constant low temperature incubators, we were unable to obtain a combination constant low temperature and moisture incubator. On the arrival of the constant low temperature incubator, we set about devising a means of bringing the relative humidity under control. After trying many things the writer adopted the method of placing enough plants or water vessels in chamber E (fig. 3) to bring the relative humidity to 100°, then when the relative humidity reached the desired point to prevent its further rise by passing the air over calcium chloride.

An exhaust fan A (figs. 2 and 3) was placed in the rear wall of the chamber E and the air led through a $2\frac{1}{2}''$ passageway into a leaden box F (fig. 3) partly filled with calcium chloride, and from there through a similar passageway B (figs. 2 and 3) back into the chamber. The fan, passageways, and leaden box are all included in the packing space of the incubator wall. A strand of human hair, after having the oil removed from it with sulphuric ether, was stretched in an adjustable brass frame. A lever was attached by its short arm to this hair in such a way that variation in the length of the hair strand would cause the distal end of the long arm to move through a considerable space. To this end of this arm was attached a platinum electrode which descended into a mercury-filled tube. Of course, the contact of the platinum point and the mercury was designed to close magnetic circuit P (figs. 2 and 3) and this to close motor circuit Q (fig. 3) which would set the exhaust fan in motion. So long as the platinum point remains in the mercury, the fan continues to change the air. Less than a minute after the connection is made is usually sufficient to dry the air to a point at which the contraction of the hair breaks the connection.

Operation.

In operating the incubator, it is necessary to set the automatic apparatus for both temperature and moisture. The former is accomplished by introducing a standard thermometer into chamber E (fig. 3) and when the rising temperature reaches the desired point, adjusting the electrode so that it almost touches the rising mercury column in D (fig. 2). The latter is accomplished by introducing a standardized hygrograph into chamber E. (Fig. 3) and when the rising relative humidity reaches the desired point, setting the tension of the hair strand so that any further loosening and lengthening will allow the platinum point to make contact with the mercury.

So long, then, as the heat maintains a constantly rising temperature and the ice in the tank is replenished, constant temperature will be maintained in chamber E (fig. 3) and so long as a constantly rising relative humidity is maintained in chamber E (fig. 3), and the calcium chloride is replenished, the constant relative humidity will be maintained.

Its Use Illustrated.*

Inasmuch as the data derived from use of the incubator in the study of *Toxoptera graminum* Rondani are most available, they will be used for illustration.

The determination of the optimum temperature was first attempted. The incubators were so placed that they would get the same quantity and quality of light. The moisture apparatus was set at 75° relative humidity and the temperature apparatus at different temperatures. A considerable number of individual viviparous *Toxoptera graminum* were allowed to complete their life cycles. The temperature was then changed and the experiment repeated. This process was continued until the effect of temperatures of 50° F., 70° F., 80° F., and 90° F., under constant relative humidity of 75° had been tested.

It is generally accepted that the optimum temperature of an organism is that temperature under which the organism's vital processes are most active.

The temperature under which these insects experienced the lowest mortality and produced the largest number of healthy young in a given time has been considered the optimum tempera-

*The writer desires hereby to acknowledge the aid afforded him by his student assistant, Mr. Francis B. Milliken, who under his immediate direction has tested different plans for the control of moisture and collected data from the insects under observation while the incubators were in operation.

ture. Chart No. 1, curve No. 4 shows that in our tests *Toxoptera graminum* experiences the lowest mortality at 80° F., curve No. 3 shows that the highest daily reproduction is at 80° F., curve No. 1 shows that the shortest time from birth to maturity occurs at 80° F., and curve No. 2 shows that the average period of reproduction is only a little less at 80° F., than at 70° F.

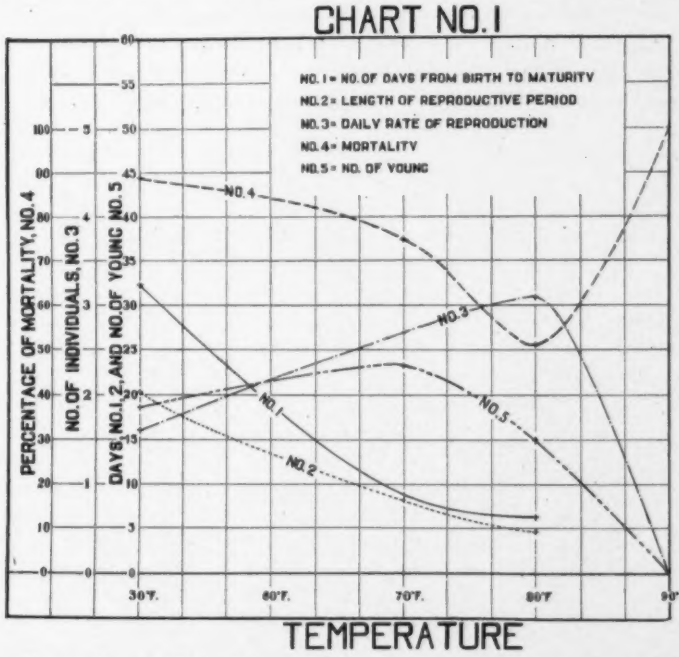


CHART No. 1.—Plotted data showing the relation of *Toxoptera graminum* Rondani to temperature under constant relative humidity of 75°. In curves No. 1 and No. 2, point at 50° F. represent the average of 6 individuals, at 70° F. 27, and at 80° F. 28. In curves No. 3 and No. 5 point at 50° F. represents the average of 6 individuals, at 70° F. 27, at 80° F. 28, and at 90° F. 201. In curve No. 4 point at 50° F. represents the average of 54 individuals, at 70° F. 108, at 80° F. 57, and at 90° F. 201.

Clearly, taking into consideration the effect of higher daily rate and shorter period of immaturity on the geometric rate of increase, *T. graminum* will under constant relative humidity of 75° produce the maximum number of progeny in a given time at 80° F. It is, therefore, reasonable to conclude that the optimum temperature for *T. graminum* under 75° relative humidity is about 80° F., possibly a little above or a little below.

NOTES ON CERTAIN SPECIES OF MAMESTRA.

By JOHN B. SMITH, Sc. D.

In 1852, Guenée described *Hecatera laudabilis* in Vol. II, p. 30 of his Noctuelites, and figured it very recognizably on Pl. VIII, figure 4. The locality given was "Amerique septentrionale," Coll. Doubleday, and the larva was described from a figure of Abbot. The type is now in the British Museum.

In 1856, Walker described *Hapalia indicans* in Vol. X, p. 359 of the British Museum Catalogue, and records two specimens, ♂ and ♀ from E. Florida, presented by Doubleday. In 1857, in Vol. XI, p. 511, of the same publication, Walker refers to *Hecatera laudabilis* Gn., gives a brief latin diagnosis and records 4 examples: 2 from East Florida out of the Doubleday collection, and 2 without locality out of the Milne Collection. He apparently had no idea that this was the same species that he had described in a previous volume.

In 1868, Grote and Robinson referred *indicans* as a synonym of *laudabilis*, in the Trans. Am. Ent. Soc. II, p. 78, after examining the types, and that reference was accepted by me and more recently by Hampson.

In 1860, Wallengren described *Hecatera strigicollis* in the Wien. Ent. Monatschr., IV, 170, and gave the locality as California. That species remained unidentified in our lists until 1891 when, in my revision of *Mamestra*, I re-published the description without, at that time, suggesting its identity with any other described species. In 1893, after seeing the British Museum collections, I referred the species, in my Catalogue of Noctuidæ to *laudabilis*, and in this reference Hampson has also followed me.

In 1875, Grote described *Mamestra illaudabilis* in Vol. VII, p. 27, of the Canadian Entomologist, differentiating it very briefly from *laudabilis*. It is recorded from California and from Vancouver Island, out of the Henry Edwards Collection, and both sexes were present. In 1881, Mr. Grote lists *illaudabilis* as a variety of *laudabilis*, and again points out certain color differences between the eastern and western specimens: differences which, unfortunately, are not constant nor, as the distribution given proves, very useful in separating the species. In my revision of 1891, I accepted Mr. Grote's ranking of the species, but was in error as to the form to which the name *illaudabilis* should be applied. In my figure of the genitalia I obviously got hold of

an imperfect or broken structure and, while it is reasonably accurate so far as it goes, it is altogether misleading as representing the real structure of the *illaudabilis* form which, obviously, I used for the dissection. In 1905, Hampson, having before him the types of Guenée, Walker and Grote, lists all names under *laudabilis*, but as "Ab. 2, *illaudabilis*," he designates those forms in which the green tinge is almost entirely replaced by white.

During the two or three years last past it has been my fortune to handle very large series of these forms from all parts of the country, and the more of them I handled, the less satisfied I became with the association. Recently, in re-arranging the species in this series, I gathered in all my material for comparison, and demonstrated to my own satisfaction two very good species; the one extending throughout the eastern and southern States and into Texas, the other through the Rocky Mountain region into Arizona and west to the Pacific Coast. The true *laudabilis* is a chunky, heavily built species with comparatively short, broad, obtuse primaries. *Strigicollis*, which must be used for the other species, is slighter throughout, the primaries narrower, more trigonate, with apices more obvious. In color, *laudabilis* when fresh, is always greenish, fading out to whitish, with the median space ranging all the way from reddish to black, often greenish below the sub-median vein. The space also tends strongly to narrow inferiorly. In both sexes the secondaries may range from blackish to almost pure white, and the general impression is that of a stout, heavily built insect. *Strigicollis*, on the other hand, never has that delicate green tinge in even the freshest examples, and many of them are almost clear white. In others there is a mossy olivaceous tinge which often darkens the normally pale portions of the wing. I have never seen a specimen with a reddish median area, but this may range anywhere from olivaceous brown to black. The median space while it tends to narrow inferiorly, never approximates the median lines so closely, and does not often tend to give a wedge-like impression. The secondaries are more uniformly pale in both sexes, and the impression, as already stated is of a slighter species than *laudabilis*.

Finally, as there was plenty of material available, I tested the male genitalic structures once more, and demonstrated the distinctness of the two series beyond peradventure. A comparison of figure 1 with figures 2, 3 and 4, will show that it is not a matter of slight differences, but of quite a radical change. In *laudabilis*,

of which specimens from New York to Texas were examined, there was not enough variation to warrant more than a single figure. The harpes are very broad at base, with a very narrow rather short extension, and a small extension at tip. There are two distinct claspers and one of them is spatulate. The corneous sheath of the penis is very long in all the examples.

Seven examples of *strigicollis* were studied, coming from Colorado, Arizona and Utah, and three figures represent all the variations found. These are practically all in the size of the penis sheath, though none is in the least like that of *laudabilis*. The differences in the *uncus* are due to differences of position, the drawings having been made with a camera lucida. Attention is especially directed to the uniformity of the outer angle of clasper at point of constriction.

Two examples a ♂ and ♀ from Kaslo, B. C., do not fit into the series of *strigicollis* and, in my opinion, represent a good species.

Mamestra restora n. sp.

Head and collar pale greenish over white; palpi black at sides, the small terminal joint pale; vertex with an admixture of black scales. Collar with a distinct black band crossing above the middle. Thoracic disc mottled with black, white and pale green. Primaries, the pale areas light greenish, basal and median lines white-filled, ornamentation otherwise black. All the lines geminate and broken. An irregular black spot at the termination of the basal line inferiorly. Median space mostly black, marked with mossy green below the sub-median vein. The outer part of wing is black powdered, forming a black patch at anal angle, more conspicuous than in its allies. The fringes are deeply marked with black and narrowly cut with white. Claviform deeper black, extending almost across the median space. Orbicular small, round, with a blackish central dot and a greenish annulus. Reniform large, superiorly dilated, annulate with white, with a mossy greenish filling. Secondaries smoky in both sexes; uniformly so in ♀ paler at base in ♂. Beneath, primaries blackish; secondaries with blackish powderings along costa and outer margin, a dusky discal spot and an extra-median line.

Expands 1.08–1.12 inches equals 27–28 mm.

Habitat: Kaslo, B. C., VII, 10, IX, 1.

One ♂ and one ♀ in good condition. Type of maculation like *strigicollis*, but darker throughout, the paler areas shaded with green, the anal angle of primaries with a dark blotch, secondaries dark in both sexes.

It is doubtful whether I would have dared to describe this as a distinct species in spite of its different appearance, were it not for the difference in the genitalia of the male. Comparison of figure 5, with figures 2, 3 and 4 will show to what I refer. In *restora* the harpes curve evenly to the narrowly extended tip, and form no obvious angle, while the extension of tip itself is shorter and broader. The claspers are also more slender and more separated than in the allied forms, and for the present I believe that we have a very good species to deal with, although undoubtedly a recent off-shoot from *strigicollis*.

Mamestra marinitincta Harvey, was described in 1875, in the Bull. Buf. Soc. Nat. Sci., II, 273, and is evidently a local offshoot from *strigicollis*, in a different direction from *restora*. Here the angle of harpes is intensified instead of lessened, and the extension of the tip is carried further. The penis sheath is very much elongated and more like *laudabilis;* but with a very long irregular series of short spinules running longitudinally. The small clasper has been reduced to a mere vestige, while the larger has not changed materially.

Superficially the wing form of *strigicollis* is held, while the median area is an exaggeration of the tendency to narrow it in *laudabilis*. Accompanying this is the evening of the median lines and the elimination of the second element, so that they are scarcely geminate except on costal area. Thus far the species is recorded from Texas only, and most of the examples are from the Belfrage collections in Bastrop Co. In my collection is one ♀ from Kerrville, and one ♀ labelled "Tenn.," out of the Kemp collection. These two examples are very similar to each other; but may possibly be distinct from *marinitincta*. I do not think they are, at present, and await further material for closer study.

Mamestra spiculosa Grote, is a species that has always been rare in collections and the two pairs now before me I owe to the kindness of Mr. Doll. The figure of the ♂ genitalia in my revision lacks detail, and a better drawing is presented here as an illustration of an intermediate form between the *olivacea* and *laudabilis* types;—the harpes of *illaudabilis* with the tip of *olivacea* indicated by the drawn out point. The clasper is long, slender and single.

In *Mamestra stricta* Wlk., and its variety *ferrea*, the structures become more compact except for the clasper, which is longer and more slender. I have twenty examples before me illustrating

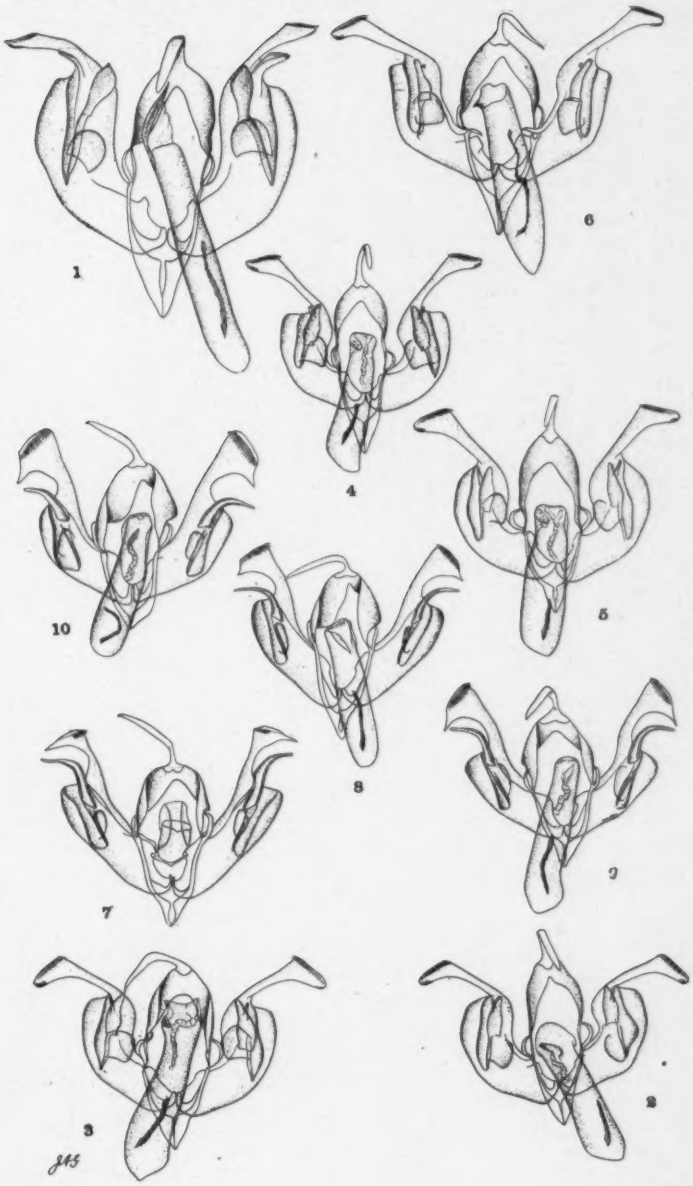
the gradations from the deep red brown to the yellowish brown type, and the species as a whole seems quite recognizable and, except for this variation in ground, very constant.

Mamestra circumcincta Smith, was described from two Californian examples representing the two sexes, which I placed with *stricta* on genitalic characters, while comparing it with *olivacea* in fascies. The ♂ type is in my collection, and another ♂ example recently received from San Francisco, California, makes re-examination possible, as well as a new figure of the ♂ genitalia available. Hampson in his Vol. V, p. 176, makes this a synonym of *stricta;* but in my opinion quite without warrant. The total habitus and ground color are different, while the differences pointed out in my original description are intensified in the fresh example which is darker and more smoky throughout. Neither example has in the secondaries any of that yellowish tinge that is in all specimens of *stricta* ever seen by me. As for the genitalia, I can claim very little for *circumcincta* as against *stricta*. The two are very much alike, and such differences as exist might easily be within range of variation. A comparison of figures 8 and 9 will make this clear.

Mamestra tenisca, recently described by me in the Proc. N. Y. Ent. Soc., is an intensified and enlarged *stricta*, and I have little doubt is mixed with the older species in collections; but I believe it to be well distinguished and take this opportunity to offer a figure of the male genitalia which, while preserving their close resemblance to those of *stricta*, depart noticeably from the type. Especial attention is directed on this point to the curved series of spinules on the penis sheath, as compared with those in *stricta* and *circumcincta*.

Explanation of Figures on Plate XXIII:

Fig. 1. Mamestra laudabilis, from N. Y., Ga., and Fla. specimens.
Fig. 2. Mamestra illaudabilis, from Ariz. and Denver, Colo., specimens.
Fig. 3. Mamestra illaudabilis, from Arizona, desert specimens.
Fig. 4. Mamestra illaudabilis, from Utah specimen.
Fig. 5. Mamestra restora: from type ♂.
Fig. 6. Mamestra maritinitincta: Texas example.
Fig. 7. Mamestra spiculosa: Arizona.
Fig. 8. Mamestra stricta.
Fig. 9. Mamestra circumcincta.
Fig. 10. Mamestra tenisca: from one of the para-types.



J. B. Smith.